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Relation of Water Rates to Living Costs

By Frank C. Tolles

A paper presented on Oct. 11, 1946, at the Ohio Section Meeting, Columbus, Ohio, by Frank C. Tolles, Partner, Havens & Emerson, Cons. Engrs., Cleveland, Ohio.

IT is appropriate at any time to ask whether water rates must move with living costs, but the question is particularly pertinent during the current marked surge in the cost curve. Manifestly, in any industry, the averaged charges for goods or services must, in the long run, be responsive to the price fluctuations which affect production. So it is with the unsubsidized sale of water, whether it be regarded as the function of government or of the privately owned utility. Although the private utility is subject to the same influences as affect the public enterprise, it is the municipal plant that will be considered in this discussion.

Financial Characteristics

The financial structure and the financing requirements of the municipal system for producing and distributing water are not complex. Fundamentally, the system is a self-supporting institution which seeks little or no profit. It is, however, under the obligation of furnishing a consistently high quality product and of meeting the reasonable needs of the community. Moreover, because water is important to many industries, the local plant and the charges for service may be important factors in establishing the economic potential of the area which is served.

The costs of municipal water service are made up of: running expense, which includes material and labor for operation and maintenance; capital charges, as interest and bond retirement; and expenditures for enlargement and major replacements in the system. These several subdivisions of cost are basic, but they have different priorities in their claims upon income. Thus, running expense is a repetitive item which is palpably essential to operation, but the costs which are allocated to expansion of facilities are often

periodic and are in the position of a residuary legatee, which takes what is left. Debt service, also with high priority, is in still another category in the amount and duration of its claims upon income, and it may dwindle to zero.

Water Rates

Base rates for the support of a water system should provide adequately for these several classes of expense, and it is not intended to imply that the setting aside of one or another item is proper in administration or finance. The fact remains, however, that many municipal systems weather periods of extreme price fluctuation only by deferment of replacement. Thus there are systems which have marked need for rehabilitation but are lacking in the reserves which normal budgeting would build up for that purpose. Undue deferment of replacement is poor business, but planning which accords expense to a financially convenient period, in which prices are also more reasonable, is certainly desirable. Enlargements of plant likewise come into this class of periodic demands which are properly the subject for planning and timing, although occasionally such expenditures may result in additional revenue which supports the added debt.

In considering the characteristics of municipal water works financing as they may bear upon the charges for service, it must be remembered that rates are sometimes subject to the approval of legislative bodies. It is probably generally true that considerations of policy or politics make water rate schedules rather resistant to upward revision. The practical effect of this condition is to make frequent changes in base rates difficult as well as undesirable.

It is perhaps needless to observe that municipal water systems vary greatly in the division of their total expense. Thus, there are systems in which the dominant cost is that of labor or of labor and material. There are water works which are free from debt and those that are heavily burdened. Further, some systems are static and others show rapid growth and consequent need for new capital. This diversity of income requirements makes it impossible to draw general conclusions about the needs for rate changes. Each system must be subject to determinations in the light of its own peculiar circumstances.

Influence of Prices

This outline of basic financing needs for municipal water works developments is offered as a prelude to judging the influence of price fluctuations on the rate structure. The degree of fluctuation of price in materials and labor that one should expect to encounter must be considered, as well as their frequency. Water works materials consist chiefly of fuel or power for pumping, chemicals for purification and cast-iron pipe and other building materials for new construction. Each of these can be studied for price behavior, but a more comprehensive, though more restrained, picture is afforded by the movement of the wholesale commodity index, which is determined by the U.S. Dept. of Labor from the prices of several hundred items of a wide variety of goods. Computation of this index, extended back to early years, shows that, within the past 150 years, this country has experienced three extreme price surges. These fluctuations, which included inflation reflective of national events, were separated by intervals of 50–55 years. Another rise of this na-

ture is forming now, although there is some possibility that it may not reach the single-year extreme of past periods of inflation.

Although the water rate structure must provide for these rare periodic extremes of high prices, the chief interest in problems of year-to-year operation is with the more frequent changes. If attention is centered, therefore, on fluctuations which occur within 10-year periods of the last 30 to 50 years, there will be found price shifts of from 5 to 12 per cent above or below average values for the given period; and it is only when the period is shortened to four or five years that steadiness in commodity prices appears.

If the study is narrowed to individual products, instead of the Bureau of Labor commodity index, the price behavior may be quite vagrant, as it is for cast-iron pipe. Other elements, such as power and fuel, will follow more closely the general commodity pattern. But, however they are considered, one must conclude that a rational review of base rates is in order every five years or so. If rates are to be in effect for longer periods, such as 10 years, they should be based on computations that include leeway for total price changes in materials of the order of 15 per cent.

Wages

Such is the situation with water works materials. For wages, the story is analogous, but in a somewhat different pattern. Over a long period in the past, wages increased steadily and moderately. Recession was slight. Starting in 1910, however, there was a decided wage movement upward, broken twice by sharp but brief setbacks. In over-all movement during this period, wages outstripped the rate of increase in living costs but, in per cent of gain, did not reach the high peak of commodities. Although change has not been uniform, wages in industry and in construction may be viewed as having increased about 25¢ per hour in each of the past three and one-half decades. The rate of increase during the last 10 years has been about 30 per cent in the construction industry, but has exceeded 100 per cent in the factory.

Statistical data making up the wage curve afford no clue to the future. Some prophets look for a further rise of 10 per cent within the near future, and this may harmonize with the changed relationship between wages and living costs since 1940. For a longer futurity it would appear doubtful whether wages can continue to hold the entire advantage which they have gained. Wages in the field of water works operation probably move more sluggishly than in industry. Retirement rights, age of personnel, continuity of work or other factors might account for some differential—and properly—but a review of service charges should include a consideration of whether the wage scale within the department is at proper level.

General Relationship

What this inquiry set out to do was to determine whether water rates must follow the cost of living. The answer to this question must be that charges for water should not and, in all practicality, cannot, fluctuate directly or even closely with such cost. Unsubsidized, water rates must, however, be attuned to cost through periodic review and adjustment. The only alternative to readjustment is the cushioned or padded rate schedule which is fundamentally unfair to the customer and, for privately owned utilities, is vulner-

able to attack. Schedules which provide for revision of charges through changes in the discount do not lessen the need for occasional stock-taking, although, in a given instance, they might prove a convenient means to readjustment.

Readjustment of rates to meet costs of the future must rest upon forecast and judgment, and it is accordingly proper to include a reasonable allowance for contingencies. Today, moreover, wartime impediments to construction have prevented many systems from keeping abreast with demands for service, and have even encroached upon a proper safety factor in supply, purification or distribution. If available reserves are not sufficient for meeting these accumulated deficiencies, the need should be met by the provision of new capital in bulk, but, afterwards, normal extension should come from income.

It has already been suggested that a retrospect of price changes would suggest prudent provision for the future. Applying these data to a particular case in which the division of expense is 33 per cent for operating labor, 19 per cent for operating material, 23 per cent for debt service and the balance of 25 per cent for extensions and major replacements, it might well be that income from rates determined during periods of rising prices should be 12 to 15 per cent above current expenses to safeguard against further price increases in the immediate future. This view also includes recognition of the fact that increased consumption within system capacity results in returns which more than carry the added expenditures for power and for material. Other instances of different cost characteristics might yield different answers to the problem of protective financing.

An allowance of 12 or 15 per cent to meet future increases in a rising economy would not of itself meet the marked upsurges of price. For these, the only safeguards are reserves which might aggregate up to two or three times the annual expense for operation and for debt service. In lieu of reserves in such amount it would be necessary to encroach to a greater or lesser degree upon other reserves which have been accumulated for new construction. Fortunately, emergencies of this nature are relatively infrequent.

Summary

The subject of rate changes to meet changes of cost admits of ramified discussion, but enough has been said to support the following conclusions:

1. Water rates fairly determined cannot be changed with frequency, but they do require periodic review and possible readjustment in order to assure the income needs of the system. So stated, the intent is one of meeting rises in cost, but a counter obligation is that of reducing rates when costs admit. Need for readjustment might come, further, from reduced water sales during a prolonged depression.

2. Review such as is suggested should certainly be made every 10 years, and, preferably, at shorter intervals, depending upon economic conditions and the prospects for the future.

3. Revenue derived from water sales should cover all elements of cost and with insistence upon short-period reserves allocated to new capital, and upon long-period reserves for protection against inflation years.

Indeed, the whole matter of stabilizing water rates to offset the inability to readjust charges frequently and quickly is bound up in the provision of proper reserves.

Enlargement of the Baltimore Water Supply System

By Schuyler C. Blackburn

A paper presented on Sept. 11, 1946, at the Four States Section Meeting, Lancaster, Pa., by Schuyler C. Blackburn, Assoc. Engr., Bureau of Water Supply, Baltimore, Md.

THE city of Baltimore, Md., first became a purveyor of water in August 1854, when it purchased the system and properties of the Baltimore Water Co. for the sum of $1,350,000. During the following year the Water Dept. was organized and took over the management of the system.

The Baltimore Water Co. had been functioning since early in the 19th Century. The system it sold to the city consisted of two mill ponds having a combined capacity of approximately 10 mil.gal., two reservoirs with a total capacity of 25 mil.gal., a pumping station and approximately 50 miles of small-size water mains.

It immediately became apparent that this supply would be insufficient, and means for enlarging the supply to meet the expected demand were discussed by various municipal and civic organizations. The original supply was taken from Jones Falls, near what is now the downtown section of Baltimore. Considerable controversy arose between the proponents of an enlarged Jones Falls supply and those who favored changing the source to the stream known as Gunpowder Falls. Finally, on July 7, 1857, the decision was reached to use the upper reaches of Jones Falls as the source of the improved water supply system.

Meeting Emergencies

In 1858 construction of a dam, known as Lake Roland Dam, was begun about five miles from the center of the city on Jones Falls. It was completed in January 1860. Improvements were made throughout the next decade, totaling approximately $4,000,000 by 1867. Two years later, with the occurrence of a severe drought, came the first of a series of near-disasters. The city managed to pull through on this occasion, but three years later it was caught in another serious drought. Since it was necessary that action be taken quickly, a temporary supply furnishing 10 mgd. was constructed, consisting of a pumping station and a 36-in. discharge main, which pumped Gunpowder Falls water over the divide into the Jones Falls valley. This served very well as a temporary expedient, but danger still threatened. In 1874, two years after the temporary supply from the Gunpowder Falls was constructed, the decision was reached by the Water Board to construct a permanent supply from the Gunpowder Falls. This proposal was ratified by the voters at the November election of that year.

Development of the Gunpowder Supply was started in December 1875 and completed in October 1881. The

works consisted of a dam, approximately seven miles north of the city, a tunnel from the dam into the city and two distributing reservoirs. The cost was somewhat more than $4,500,000.

Many improvements followed during the succeeding years, and the Baltimore supply seemed to be ample. This opinion was justified when, in February 1904, the greatest catastrophe in the history of the city—the Baltimore Fire—occurred. For the two days that the fire raged, the Water Dept. was called upon to supply a demand approximately 80 per cent greater than normal, and for a week from the start of the fire the demand was approximately 40 per cent greater than normal.

In 1910, Freeman and Stearns, who had been engaged by the city as consultants, recommended improvements of the Gunpowder Supply by the construction of a new dam at Loch Raven and a filter plant; they also recommended that the Jones Falls Supply be abandoned. These recommendations were followed, and, in 1915, the new dam and filter plant were placed in service. Again the city's water supply system seemed to be ample, but, in 1918, by an Act of the Legislature, the city of Baltimore annexed 56 square miles of territory, an increase in area of more than 150 per cent, and it was obvious that, with the increased population, it would be necessary to provide further for the needs of the citizens.

Again consultants were called upon, and, in 1920, Hill and Fuertes recommended raising the Loch Raven Dam 52 ft. and increasing the capacity of the filter plant. These two projects were carried out, and, in 1927, both were in operation. In November 1930 construction of Prettyboy Dam on the Gunpowder Falls, 25 miles upstream from Loch Raven Dam, was begun, the project being completed in September 1933.

A drought that started in the latter part of 1929 and continued for several years again brought to the attention of the city the need for further enlargement. In 1932, three consultants, Gregory, Requardt and Wolman, were engaged to study the situation and submit recommendations. They made an exhaustive investigation of the water supply system and all the factors involved, and, in December 1934, presented their report. Their recommendations included the immediate construction of a new tunnel from Loch Raven Dam to the filtration plant, to be followed by the construction of a new and larger dam on the Gunpowder Falls downstream from the present site, this latter work to be undertaken as soon as possible.

Planning Expansion

The tunnel was constructed, but the proposed Gunpowder Falls dam was not, decision being reserved for several years. When war started in Europe, resultant industrial expansion in the city was such that the water consumption steadily climbed. Property values had increased in the Gunpowder area, making advisable a review of the cost of constructing the several projects previously considered. Again the consultants were called on and Requardt and Wolman submitted a supplementary report in January 1942.

In view of the conditions then current, the report recommended that instead of enlarging the Gunpowder Falls Supply the city should develop a new source—the North Branch of the Patapsco River (Fig. 1). This source

was selected after a review of the studies previously made of all the streams which could in any way be considered as being available to the city of Baltimore—the Susquehanna River, Deer Creek, Winters Run, Little Gunpowder Falls, Gunpowder Falls and the Patapsco River.

Following the submission of this report, there was presented to the voters

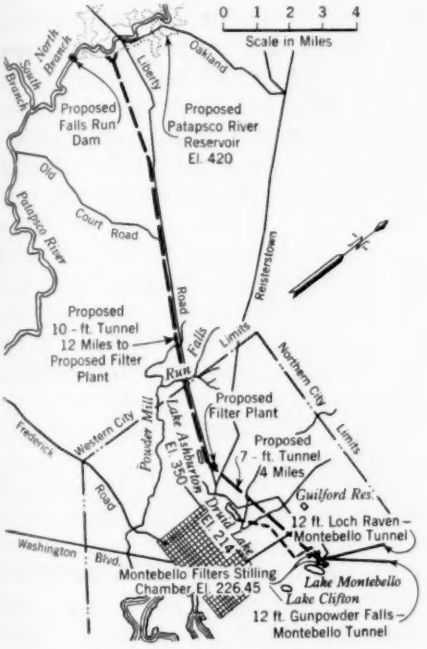


FIG. 1. Enlargement of Baltimore Water System

of Baltimore at the 1942 elections a proposal to borrow $32,000,000, a portion of which was to pay the cost of constructing the new Patapsco Development. Several civic organizations in the city opposed this loan, and due partially to their efforts and partially to the lassitude of the voters, the proposal was defeated. After this refusal of the voters to provide funds for improvements that were considered necessary, conferences were held to determine the next course to pursue.

It was decided to submit a loan proposal to the voters again, at the municipal election in May 1943, this time for only $12,500,000. Included was a portion of the Patapsco Development —a tunnel from Montebello Filtration Plant to the western city line—and a temporary works consisting of a pumping station, sedimentation basin, sanitation plant and a pipeline from the end of the tunnel as constructed to a point on the Patapsco River several miles south of the new dam site. This loan was approved. Plans were immediately prepared for the several projects enumerated and in December 1944 bids were opened for the construction of the Liberty Road–Montebello Tunnel. It happened that the date of opening bids coincided with the time when our forces in Europe were meeting with reverses—the well-remembered "Battle of the Bulge"—and the prices reflected the uncertainties that prevailed at that time. The bids were considered excessive and all were rejected. Subsequently plans for the tunnel were amended, certain economies in design effected, and the decision reached to advertise for the excavation of the shafts and about 1,000 ft. of tunnel headings. This contract is now in the construction stage.

Future Undertakings

The development of the North Branch of the Patapsco River as a source of water supply will be undertaken in several stages. The temporary work described previously has been tentatively and, it is hoped, permanently withdrawn from the program. Having passed through the critical war years without the installation of these structures which would have to be

abandoned in a relatively short time, the city has decided not to proceed with this temporary work except in an extreme emergency.

The first step in the development will be the construction of a tunnel, from the Patapsco River to the existing filtration plants at Montebello, and an intake a short distance upstream from the site of the dam that will ultimately be constructed. When this portion of the work is completed, the present Gunpowder Supply of 148 mgd. will be augmented by about 50 mgd., utilizing the stream flow of the Patapsco without impounding.

Funds are now available for a portion of this work—the tunnel from Montebello Filters to the western city line. In the early part of 1947, just before the completion of the present contract for the shafts and headings, bids will be asked for this first section of the tunnel. Plans and specifications for this section have been completed. It will be approximately 35,000 ft. in length, of which 14,000 ft. will have an internal diameter of 10 ft. with a monolithic concrete lining and 21,000 ft. will be lined with 84-in. reinforced concrete pressure pipe.

At the November 1946 election, the voters were asked to approve a loan of $10,000,000. Having gained their approval, the city is in a financial position to proceed with the remainder of the first step of the development—that portion of the tunnel from the city line to the Patapsco River. This section of the tunnel will be 10 ft. in diameter, with a concrete lining. During the first period of its use, however, it will not be lined.

When it can be predicted that a safe yield of 198 mgd. will be insufficient for the needs of the city, the second stage of the development will be inaugurated. This will consist of the construction of a dam on the North Branch of the Patapsco and the lining of the tunnel between the Patapsco River and the city line. The dam will form a lake of a capacity of 43 bil.gal. Land is already being acquired for the reservoir and, of the 8,000 acres necessary, the city now owns approximately 6,000 acres. With the completion of this second step in the development, the safe yield of the combined sources of water supply will be 243 mgd.

The third and final step in the development of the supply will be undertaken when the present filter capacity is exceeded. This will be the construction of a filter plant having a capacity of 110 mgd. to process all of the water from the Patapsco River and discharge it directly into what is known as the Middle Service areas. The site for this filter plant has been secured by the city at the location of one of the shafts of the tunnel which is under construction.

When the Patapsco Development is finally completed, all the water in the Low Service area will be supplied from the Gunpowder Falls, while the Middle Service areas will be supplied from the Patapsco River by gravity without pumping, thus enabling the city to place in reserve the two largest pumping stations now in operation in the system.

This extensive program, extending over a period of possibly twenty years, should give to the city of Baltimore two good sources of supply. A combined capacity is thus afforded, ample to supply the city's needs beyond the time when most of the present employees of the Bureau of Water Supply shall have ceased to have any interest in such problems.

Water Works Improvements for Philadelphia

By Elbert J. Taylor

A paper presented on Sept. 27, 1946, at the Four States Section Meeting, Lancaster, Pa., by Elbert J. Taylor, Chief, Bureau of Water, Dept. of Public Works, Philadelphia, Pa.

PHILADELPHIA now obtains its water from the Schuylkill and Delaware Rivers, through intakes that are all within city limits. Three filter plants are supplied with raw water from the Schuylkill and one from the Delaware.

Five main objections exist to the continued use of these sources: (1) high bacterial load in the raw water; (2) tastes and odors in the finished water; (3) red and brown water at the spigots; (4) aesthetic revulsion to "manufactured" water from contaminated sources; and (5) the hardness, generally above 100 ppm., of the water from the Schuylkill.

Treatment Problems

The high bacterial load of the raw water is the most important objection from the engineering standpoint. It is a factor that can also be used very effectively by opportunists to frighten and sway the layman. Although it is becoming generally recognized that some filtrable disease viruses are present in water containing sewage, the author has found no adequate data on the degree of dilution required to make such waters safe. It seems, therefore, that adequate sterilization for all supplies regardless of contaminant dilution is required. It is obvious, of course, that water containing large amounts of sewage requires more treatment and more careful supervision.

Tastes and odors and corrosion, resulting in red water, must be combated in most surface supplies. Where trade wastes are heavy, their control is more difficult but not impossible.

No antidote for the relief of the aesthetic sufferer can be offered, except a supply from some distant source, preferably in wooded, uninhabited mountains.

The hardness of water now present in the Schuylkill supply can be corrected without much difficulty, but at an increase in cost of between $12 and $18 per mil.gal.

These objections to the continued use of the present source of water by the city of Philadelphia form the background from which the present improvement plans have grown.

To date the only taste and odor and corrosion control measures practiced in Philadelphia are the use of as little chlorine as possible and the filtering of as much of the water as possible through slow sand filters. No facilities, not even storage space for additional chemicals, are available for the application of tested methods of taste and odor abatement.

In 1940 the city adopted a program for the rehabilitation and modernization of all its filter plants and pumping

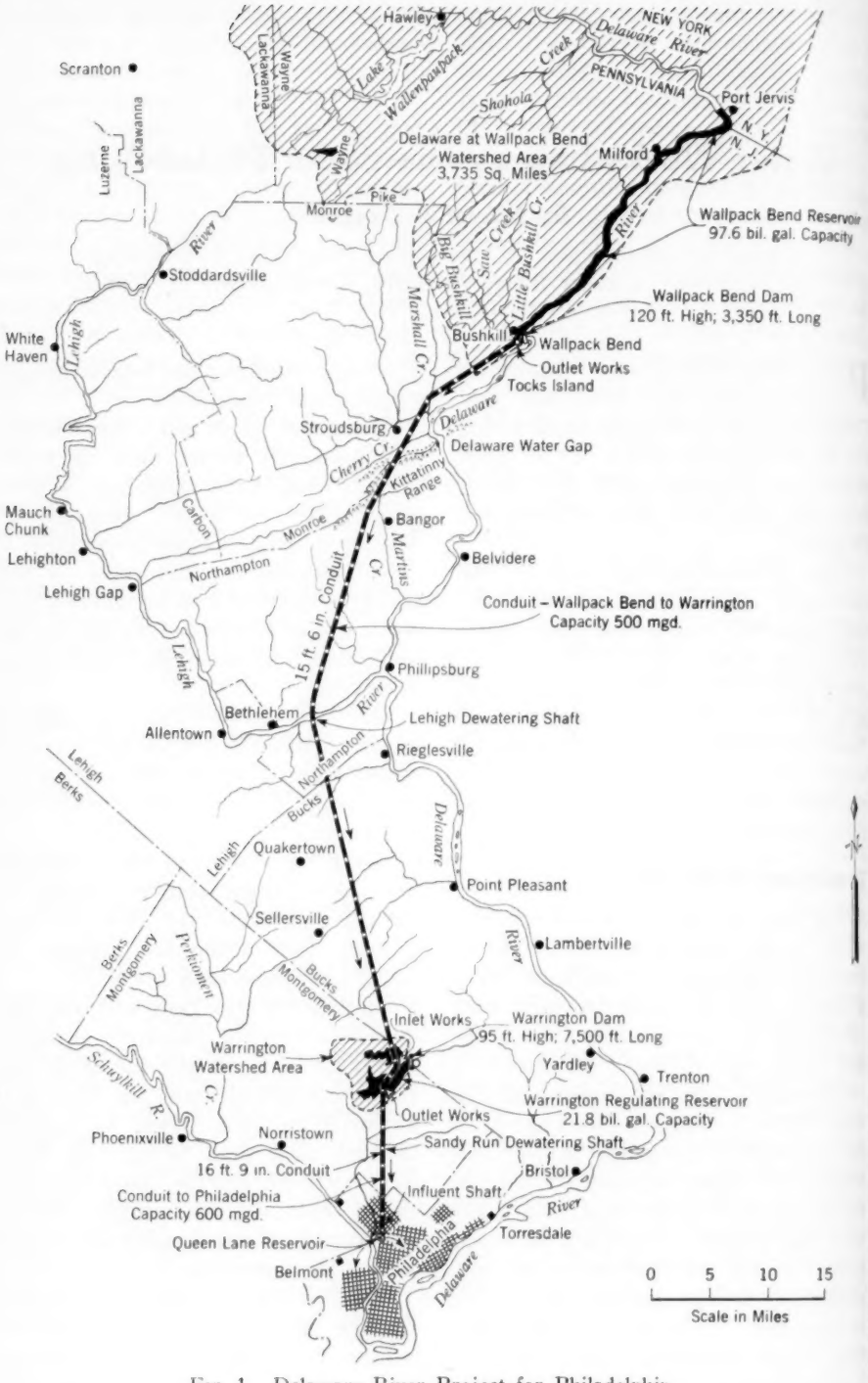


FIG. 1. Delaware River Project for Philadelphia

stations. If conditions in the nation had remained the same during the past six years as they were in 1940, it is probable that this program would now be complete. With the advent of the war, however, it was necessary to defer practically all work on purification improvements. The pumping station work progressed at a slow rate, but is now largely under way and will soon be substantially completed in accordance with the 1940 plan.

Appraisal of Improvement Plans

During the mayoralty campaign of 1943, Mayor Samuel promised that he would bring the question of a new water supply to the citizens, so that they could express an opinion on it. In the spring of 1945, the mayor appointed a water commission consisting of representatives of all groups of citizens, such as lawyers, bankers, labor leaders, newspaper men and industrial leaders. The commission appointed a Board of Consulting Engineers to review the upland sources and recommend the most desirable of them. This report was also to contain an outline of the existing works, a study of the probable effect of the river clean-up campaign on the water from the existing sources and estimates of revenue required to carry out various improvements. The report of the Board of Consulting Engineers was filed with the commission in the spring of 1946.

Preliminary discussions of the engineers' report influenced the City Council to hold a series of public hearings on the question of water supply, and all interested people were requested to come before the council to express their opinions and make recommendations. During these hearings the Bureau of Municipal Research filed a summary of the various schemes or programs which had been proposed during the hearings, and made recommendations which are often referred to as the "Bureau of Municipal Research Plan."

Recently, the Philadelphia Chamber of Commerce and Board of Trade filed with the mayor their own recommendations, which follow closely those of the Bureau of Municipal Research, except that they included confirmation of the council's action in authorizing immediate improvements in the taste and odor control. This action of council, generally referred to as the "Council Program for Immediate Improvements," followed the many discussions of the hearings which emphasized the present lack of taste, odor and corrosion control in the city system and espoused the efficacy of various remedies.

A summary of the plans mentioned above will be outlined to give a picture of the relation of the council plan to the other proposed plans. At present the only accepted plans are those adopted by the council for immediate improvements, but it is hoped that all of these improvements will fit into any of the contemplated plans.

The 1940 plans for rehabilitation included the construction of modern rapid sand filter plants, including flocculation and settling basins and all the modern equipment usually included in this type of installation. At each filter plant, it was planned to utilize the existing slow sand filters as polishing units so that the treatment provided would include facilities for free residual chlorination, activated carbon application, flocculation, settling, rapid sand filtration, slow sand filtration and final sterilization. The 1940 Report stated that, although it was impossible to be certain that all of the facilities planned would be usable in conjunction with any upland source, future sources of supply were considered, particu-

larly in favoring one improvement over another.

The report of the board of consulting engineers to the Mayor's Water Commission recommended taking all the water for the city from the Delaware River, either at Yardley, which is a short distance above the Trenton Dam, or through a closed conduit from the reservoir to be built at Wallpack Bend, several miles above the Delaware Water Gap (Fig. 1). The former plan provides for the construction of a reservoir to furnish the necessary compensating water in the river to allow withdrawals at Yardley up to 500 mgd. The cost of this project was estimated at $137,456,000. To provide water free of the pollution entering the middle portion of the river and also obtain a gravity supply, the board recommended the alternate plan of a closed conduit to an equalizing reservoir adjacent to the city limits. This equalizing reservoir would have a water surface of sufficient elevation to deliver 500 mgd. of water to the city limits approximately at elevation 240. The estimated cost of this project, without improvements inside the city, most of which are required regardless, was $284,000,000.

To finance the alternate plan, it will be necessary to double the revenue obtained at present. Some newspapers estimated that this doubling of the water rates would amount to about 1¢ per capita per day. This figure, of course, sounds small, but is seen more clearly when considered as an additional $8.00 to $12.00 a year for each family for domestic use. The most important effect of this doubling of rates would be the possibility of driving away many of the industries which the city has been able to acquire and hold over the past years because of the reasonable cost of large quantities of water.

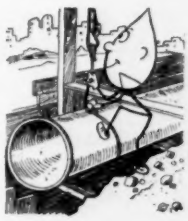
The Bureau of Municipal Research plan recommends the abandonment of the Schuylkill supply and the furnishing of water to the filter plants now located on the Schuylkill watershed from the Delaware River. This water from the Delaware River is to be taken from the tidal basin from a point just below the Trenton Dam. The assumption is that the bacterial quality of the water will be approximately the same as that now used in Trenton, which meets the standards recommended by the U.S. Public Health Service for water treated by rapid sand filtration and pre-chlorination only. The estimated cost of this plan is $82,000,000, and it is well suited to step development, so that financing within the existing rate structure appears feasible.

Approved Program

The program authorized by the council for immediate construction includes: the installation of facilities for feeding activated carbon at Belmont, Queen Lane and Torresdale Filter Plants; the installation of a pre-ozonation plant at the Belmont Rapid Sand Filters; installation of facilities for free residual chlorination at Queen Lane Filter Plant; completion of filter plant improvements at Queen Lane as proposed in the 1940 Report; completion of the filter plant improvements at the Belmont Filter Plant as included in the 1940 Report; and the construction of an additional filtered water effluent conduit and reservoir connections at the Torresdale Filter Plant. No improvements in the filter plant at Torresdale are included in this program because this plant on the Delaware

River has a water surface approximately at elevation 30, and the filtered water is pumped into the distribution system. Additional filter plant improvements at Torresdale as planned in 1940 fit in with the Bureau of Municipal Research and Chamber of Commerce plans, and with plans to take water at Yardley, but do not satisfy the requirements of the alternate plan for an upland source proposed by the board of consulting engineers to the Mayor's Water Commission. To obtain the benefit of gravity flow as proposed in this plan, it will be necessary to construct this 300-mgd. plant on high ground above elevation 230.

It is apparent from this brief outline that the only unique part of the present approved program is the planned installation of an ozonation plant to treat 36 mgd. before it goes through the rapid sand filter plant. Meanwhile, the Bureau of Water, backed by the late Director McLaughlin, Mayor Samuel and the City Council, is arranging facilities for taste, odor and corrision control, and hopes to have a definite improvement in the quality of tap water before the end of next year.



Rights of Way for Pipelines

By Ingwald E. Flaa and William C. Renshaw

A paper presented on Oct. 25, 1946, at the California Section Meeting, San Francisco, Calif., by Ingwald E. Flaa, Hydr. Engr., and William C. Renshaw, Asst. Engr., both of the Water Dept., San Francisco, Calif.

PLANNING the acquisition of a pipeline right of way—that is, determining the type of interest to be acquired in the land and the terms and conditions to be embodied in the deed—presents somewhat the same problem as planning the pipeline itself. It is essential, on the one hand, that anticipated requirements be met, allowing an adequate safety factor, and, on the other hand, that the cost be consistent with the benefits received. A lower limit on the rights to be obtained is established by the consideration of safety, and an upper limit by the cost. In order to strike a proper balance between the two, it is necessary to consider many factors, some common to an entire locality, some peculiar to a particular problem.

There are, of course, too many variables affecting the problem to permit a simple conclusion that a right of way either in fee or in easement is to be preferred. It probably can be said, however, that one or the other is more apt to prove advantageous under certain conditions.

Rights of Way in Fee

Rights of way in fee are usually thought of as falling into one of two groups: those in "absolute fee" and those in "conditional fee." Both include actual title to the land, but in absolute fee there are practically no substantial conditions or reservations to the title. In conditional fee, there may be only one or two restrictions of minor importance, or there may be enough to tie the pipeline owner hand and foot.

Under an absolute fee title, the purchaser of the right of way owns the land unconditionally. He can use it as he sees fit, subject only to such governmental restrictions as apply to other land in the vicinity. He can fence it; he can construct buildings on it; he can lease it to others. In short, he has substantially complete freedom to install his own pipes and appurtenances; and, at the same time, he is protected from interferences resulting from use of the land by others.

A conditional fee title, on the other hand, carries with it only part of the interest in the land. It may restrict the purchaser in his use of it, leave some rights for its use with the original owner or, more usually, both. How much freedom the purchaser of the right of way may have, and how much protection from interferences is afforded him, depends on the terms and conditions of the deed.

Characteristics of Easements

The legal distinction between a right of way in conditional fee and an easement is clear-cut; but, from the practical standpoint of what the pipeline owner may or may not do, and what he is or is not protected against, the two may be nearly identical. Except for tax liability, the rights and privileges conveyed depend not so much on the particular legal form used, as on the terms and conditions embodied in the deed or other instrument. In fee transfer, title to the land passes to the purchaser but any number of rights to its use may be retained; in an easement, rights to limited use of the land are transferred while title to it is retained by the original owner.

Easements, like conditional fee transfers, vary widely in the rights and protection conveyed to the purchaser. In their simplest form, they convey merely the right to lay and maintain one or more pipelines across a piece of property in a certain general location, affording the pipeline owner little protection against uses of the land which adversely affect its suitability for right of way purposes. This type was common in early days but has given way largely to more elaborate forms. San Francisco, at present, generally uses one which describes a strip of land of definite width and contains a number of provisions designed to protect both the city and the grantor. The more important clauses provide for access for city forces over private roads and adjacent land, specify a minimum depth of burial for the pipe, prohibit the grantor from using the land in any way that will interfere with its use as a pipeline right of way, permit the construction of roads, streets and utilities across, and sometimes along, the right of way at locations and grades subject to approval by the city, prohibit the city from fencing the right of way, and prohibit the grantor from constructing buildings or other structures, planting trees, or making fills above a certain depth on the described strip.

The width of the easement described will normally correspond to the width that would be purchased in fee if that method of acquisition were used. It may vary from just enough to accommodate one pipe and permit access for repairs—say 10 ft. with a temporary right to use adjacent land for construction purposes—up to possibly 100 ft. or more if several additional future lines are contemplated. A usual figure for large lines is 40 to 60 ft., which allows sufficient working space for construction and can accommodate two pipelines.

Absolute Fee

There is no doubt that a continuous right of way in absolute fee provides a greater factor of safety than other types. It cannot fail to meet any possible requirements and affords positive protection against unforeseen changes in conditions. There are several reasons, however, why it is not always the best answer to the problem:

1. Absolute fee may be difficult to obtain, except in short, disconnected sections. Obviously, if an area is fairly well developed and roads, streets and utility easements cross the proposed line at short intervals, absolute fee title can be obtained only for the undeveloped stretches. It is questionable whether, under such circumstances, an absolute fee title has any great advantage over a conditional fee or easement, as obstructions and interferences cannot be prevented where they are most likely to occur.

2. The cost is apt to be high, due to severance damage to the property crossed by the right of way, unless it happens to run along a boundary or a natural barrier.

3. It may be difficult to continue to hold a strip of land in absolute fee for any considerable distance through an area after it begins to develop. The barrier it forms is almost certain to be broken, sooner or later, by public pressure, permitting roads, streets and utilities to be constructed across it. As a result, much of the protection from interferences afforded by the absolute fee title would be removed at just the time when it would begin to be of most value.

4. There are two sources of continuing expense associated with a right of way in absolute fee. One is taxes on the land, which applies also to the conditional fee, and the other is surface maintenance, including prevention of fire hazards due to growths of grass and weeds, removal of accumulations of paper and rubbish, and control of ground squirrels and other rodents.

In spite of these disadvantages, there are certain situations in which choice of this type of right of way may be definitely indicated. If the pipeline route is through subdivided land, where the right of way covers too large a portion of lots to permit their use for building purposes, the lots will have little remaining value and the fee title might as well be taken. Also, trestles, buildings or appurtenances aboveground may prevent surface use of the right of way and passage across it. Full severance damages will necessarily be paid in this case, and the burden of maintenance will fall on the pipeline operator by default, regardless of what kind of interest is purchased. A third situation arises if protection of structures or appurtenances requires that the right of way be fenced. A fourth might arise when future needs are uncertain but where there is a strong likelihood that construction aboveground may become necessary. If the line is of sufficient importance to warrant it, the additional cost of a right of way in absolute fee might be looked upon as insurance against improvements to the land that might make the cost of future construction aboveground prohibitive. These are all rather special cases.

Conditional Fee vs. Easements

If something less than the absolute fee title is to be taken, the question arises whether the conditional fee or the easement will be more advantageous. As mentioned above, almost any combination of rights and obligations for either party to the transaction can be obtained by either form. The choice between the two must be based on other considerations, arising from the various differences between the conditional fee and the easement.

The first, and probably most important, of these differences, is the method of defining the respective rights of the two parties to the transaction. Under an easement, the portion of the interest in the land transferred to the pipeline owner is defined. He is permitted to do only the things listed and is protected against things the grantor may do only to the extent specifically set forth. Under the conditional fee form, on the other hand, the interest retained by the grantor is defined. The pipeline owner is not restricted in his use of the right of way except as set forth in the instrument, and is protected against all acts by the grantor that are not specifically permitted.

Under a perfectly drawn instrument of either type, of course, the pipeline owner would obtain sufficient rights to serve his purpose and would be adequately protected against adverse acts by the grantor. Perfection, however, is hard to obtain. The normal instrument is apt to contain errors or ambiguities. There may also be omissions due either to error or to the difficulty of anticipating changes in land use which may occur in the future. A lapse of twenty or thirty years may make new uses profitable—uses which would have been prohibited had they been thought of at the time the right of way was purchased. In such cases the conditional fee form has distinct advantages, for the pipeline owner gets all interest in the land except what is specifically reserved to the grantor. His interests will not be affected adversely by omissions or by failure to anticipate future conditions.

A second difference is in the matter of taxes. A fee title carries with it liability for their payment. This entails an extra annual expense. There was a time when this was one of the principal arguments in favor of the fee title, based on the possible loss of an easement through sale of the land for delinquent taxes. No instance of this having actually occurred has come to the attention of the authors, but apparently it was, at least theoretically, possible. A 1941 amendment to the revenue laws of California (1), however, appears to have eliminated the danger in that state. Easements are now included among the specific exceptions to the general rule that a tax deed conveys the land free of encumbrances. It might be noted in this connection that one method sometimes used in the past to avoid the danger of losing an easement in this way is to have it assessed separately and to pay the taxes on it. Such taxes should be somewhat less than the full taxes on the land.

There is little choice in cost between the conditional fee and the easement, as the purchase price of the right of way itself, exclusive of severance damage, is influenced very little either by the kind of title taken or the terms and conditions. Theoretically, it might be expected that the price would vary more or less in proportion to the interest transferred, until, for the absolute fee title, it would reach the full value of the land. Actually the price, exclusive of severance damage, is apt to approximate the full value of the land regardless of the interest taken.

This inconsistency results from a combination of several factors characteristic of right of way acquisition. For example, what takes place is generally not a normal real estate transaction between the well-known "willing buyer" and "willing seller." The attitude of the average seller could probably be described, by a gross understatement, as reluctant. Also, speed is often a prime consideration. Again, the price is usually small compared with the cost of the pipeline to be accommodated. The net effect is that it is frequently economical, in the long run, to pay more than the theoretical value in order to avoid delay. This, in effect, tends to establish an accepted price level above the true value, and influences all purchases whether by negotiation or as a result of court action.

Conclusion

The foregoing discussion has been, necessarily, rather brief, touching only the high spots of the subject of rights

of way. It is hoped, however, that it has been sufficient to indicate in a general way the reasons for the conclusions reached by the authors. These conclusions, applying particularly to the use of large pipelines under conditions similar to those in the San Francisco Bay area, may be summarized as follows:

1. The most desirable type of right of way is one in absolute fee. Frequently, however, the absolute fee cannot be justified, whether because severance damage makes its cost excessive; because it is not obtainable except in short, disconnected sections; or because there is difficulty in retaining the full fee title until the time when its potential advantages will be fully realized.

2. Absolute fee title to the portions involved should generally be acquired whenever: contemplated construction aboveground will prevent use of the land and passage across it by the original owner; it is deemed imperative to provide for possible future construction aboveground in an area where later acquisition of the necessary rights might be impracticable; or the right of way will render a lot or other small holding valueless for building purposes.

3. If it is not practicable to acquire a right of way in absolute fee, the more positive protection afforded by a conditional fee title, compared to an easement, will more than outweigh the small additional cost involved in payment of taxes.

Reference

1. Revenue Laws of California, annotated. 1941. Section 37-12 (d).

Booster Pumping on a Large Closed Aqueduct

By H. A. Knudsen

A paper presented on Oct. 25, 1946, at the California Section Meeting, San Francisco, Calif., by H. A. Knudsen, Mech. & Elec. Engr., East Bay Municipal Utility Dist., Oakland, Calif.

IN 1943, it became urgently necessary for the East Bay Municipal Utility Dist. to increase the supply of water to its distribution system. Under the circumstances then prevailing, there was little choice in methods. Prompt action was required either to construct a new aqueduct or additional pumping facilities. As the material and manpower requirements of an additional aqueduct, five or six feet in diameter and more than 80 miles long, were tremendously greater than those of a new pumping plant, scarcities dictated the choice of the latter expedient. Thus, plans were made to install pumping facilities to boost the flow in the existing aqueduct.

The installation of a large booster plant in a closed aqueduct, 61, 63 and 65 in. in inside diameter, more than 80 miles long and of 70- to 90-mgd. capacity, was a problem of no mean proportions. Large sums of money were involved and forces of more than ordinary magnitude had to be reckoned with. Due to the stress of the times, economic considerations had to be subordinated to the urgent need for more water. Fortunately, however, the financial investment in the pumping facilities, compared with that estimated for the construction of an additional pipeline, also proved that the project was well within sound business requirements.

Basis for Design

The basic requirements for the design of the pumping plant were that:

1. The flow was to be increased as much as possible with a single booster.
2. Pressures developed were not to exceed those which controlled the design and construction of the aqueduct.
3. Surges which might be destructive to the pipeline were to be fully controlled.

To fulfill the first requirement, it was imperative to have accurate knowledge of the flow characteristics of the pipeline. This knowledge was somewhat difficult to obtain because the working pressure of the pipe under gravity flow varies inversely with the diameter and because a number of taps have been added to the line. As shown in Fig. 1, both inlet and outlet sections of the pipeline are at higher elevations than the control section, so that the diameter decreases toward the discharge. This design was chosen to limit the maximum thickness of the plate.

One pumping plant with surge line was constructed with the line, and between gravity and pumping operation two rates of flow were available for testing.

Analysis of the flow test data and operating statistics indicated that the Williams-Hazen formula usually ac-

FIG. 1. Plan and Profile of Mokelumne River–East Bay Aqueduct

cepted for pipeline design did not apply, but that more consistent results could be obtained by the use of Kutter's formula. Consequently the latter formula was used in extending flow calculations to the desired higher rates. In the acceptance tests, to be described later, the use of Kutter's formula was fully substantiated.

Having determined the flow characteristics, it was a relatively simple matter to locate the plant for maximum flow and safe pump discharge pressure. Figure 1 illustrates the conditions for final location. A slight deviation from optimum conditions had to be made because of foundation limitations.

Surge control appeared at first to be the most troublesome requirement. A surge relief line had been constructed with the aqueduct for the existing plant, but, because of the flat terrain surrounding the new plant, this type of control was not practical. To construct a pond and to drop the suction pressure into it, thus separating the pipe sections on opposite sides of the plant, was equally out of the question. Some successful experience had been gained by the use of an ordinary swing check valve installed as a dividing gate in the line to separate the pump suction and discharge. This method was chosen for surge control at the new plant and the results that have been obtained are most gratifying (1). On power failure, the transition from pumping to gravity velocities is achieved with the accompaniment of inconsequential pressure oscillations.

The Plant

The type of design chosen, although not unusual, does embody some features not ordinarily found in a pumping plant. To gain as much head as possible on the suction, the pumps were placed below ground, thus maintaining positive pressure at all times. Vertical pumps proved to be the most economical and, in that respect, are definitely unusual. Single-stage units, with double suction and double volutes to operate at a total head of 415 ft., were specified and installed. Very satisfactory results and high efficiencies were obtained.

The motors and all the electric switching equipment are of the totally enclosed out-of-door type. The motors are cooled by means of water-cooled heat exchangers in the airstream. The only housing provided is a small concrete structure which houses the control board and operator's room, storage battery, exciters for the 4,000-hp. synchronous motors, a small shop and sanitary facilities.

Completely automatic shutdown protection was provided, so that the only sudden shutdown which the plant may experience is that due to power failure. The usual sources of trouble, such as heated bearings or windings, or failure of lubricating oil or cooling water supplies, are wired to relay circuits which shut the plant down automatically and provide a visual indication of the source of trouble.

Sleeve-type throttling valves are installed in the pump discharge and are arranged to close before power to the motors is cut off on normal or relayed shutdown. When the plant is placed on the line, these valves open slowly after motors are up to speed. A telephone line and pressure controls coordinate the safety measures with the older plant.

Acceptance Tests

The specifications required that one of the motors be assembled and completely tested in the factory at the

FIG. 1. PLAN AND PROFILE OF MOKELUMNE RIVER–EAST BAY AQUEDUCT

manufacturer's expense and in the presence of representatives of the district. Two motors were required, each of 4,000-hp. capacity at 900 rpm., when operating on 3-phase alternating current at 2,300 v. They are synchronous motors with separate exciters. Although it is not the purpose of this paper to describe these motor tests, it may be said that the efficiencies obtained thereby were used in computing the pump efficiencies from the field tests. Electrical test transformers and meters that had been laboratory rated were used to measure the power input to the motors during the field tests.

It is not practical, and would prove unnecessarily expensive, to make a shop test of pumps of this size. Consequently, the specifications called for field acceptance tests after installation to be conducted at the expense of the district in accordance with the test code approved by the Hydraulic Inst., with the single exception that the rate of flow was to be determined by the color-velocity method.

Two pumps, each rated at 47.5 mgd. and 415 ft. total head at 900 rpm., were installed to pump 95 mgd. of water when operating together. As it was not practicable and would serve no useful purpose to test the pumps separately, they were tested in parallel, as stipulated in the specifications.

The first measurements of flow and friction loss on this aqueduct were performed by Fred C. Scobey (2) in 1929, when he added some coloring material to a small volume of water and timed the travel through a known distance. Later Scobey assisted in some flow measurements on a new concrete-lined pipe. It was during these tests that the district engineers became familiar with this color-velocity method of measuring flow in pipes—a procedure they have used extensively since, with some modifications in the timing of the travel of the color slug.

For the pump acceptance tests, a straight section of pipe 7,533.1 ft., in length, a short distance downstream from the discharge of the plant, was chosen as the section through which the velocity was to be measured. The pipe is of welded steel plate with an internal dip coating of about $\frac{1}{8}$ in. thickness. The steel plate is $\frac{1}{2}$ in. thick for the first 4,383 ft. and $\frac{7}{16}$ in. for the remainder of the section. During a scheduled shut-down of the aqueduct, while pump connections were being made, the inside diameter of this section was carefully measured both horizontally and vertically at intervals of 100 ft. The average of these measurements was:

Diameter	*in.*
Vertical	64.054
Horizontal	65.461
All	64.76

It will be noted that the empty pipe was slightly out of round, the horizontal diameter exceeding the vertical by an average of 1.407 in. The area of an ellipse with axes equal to the average vertical and horizontal diameters and of a circle with diameter equal to the average of all diameters differ by only 0.01 per cent; the area of the circle being the greater. This is a negligible discrepancy, even if the partial correcting effect of water pressure is ignored.

Neglecting external soil pressure, an internal pressure of 190 psi. will increase the diameter by 0.027 in. where the plate thickness is $\frac{1}{2}$ in. and 0.031 where the thickness is $\frac{7}{16}$ in. An average correction of 0.03 in. was made to the diameter, making the operating diameter 64.79 in. This correction

amounts to about 0.092 per cent in the cross-sectional area of the pipe.

Potassium permanganate was selected as the coloring medium for the specific reason that, as an oxidizing agent, it would be dissipated before reaching the distribution system and thus would not become the source for complaints about discoloration of the water supply. Four pounds of this material in crystaline form was dumped into the pipeline near the center at a point about 1,900 ft. upstream from the first velocity timing point. This material was inserted by means of a stuffing box through a 4-in. gate valve on top of the pipe from which an air valve had been removed.

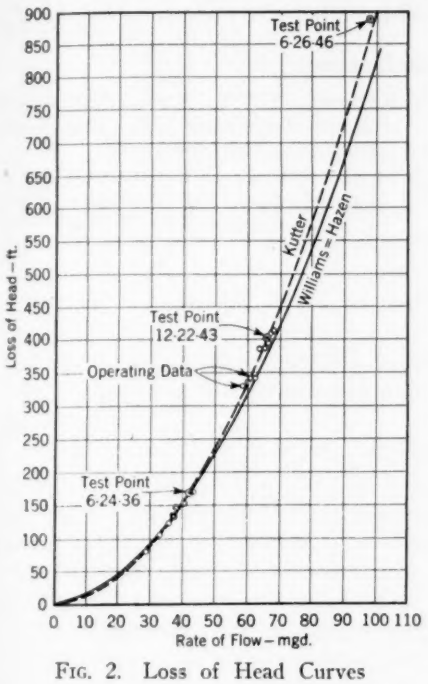


FIG. 2. Loss of Head Curves

At the velocity timing stations, water was discharged continuously through a special glass tube placed in the observation receptacle of a "Photelometer"—a commercial instrument designed to measure the turbidity of water. With slight modification, the instrument was also adapted to indicate continuously the color intensity of a stream of water. The instrument consists essentially of a photoelectric cell with a beam of light of uniform intensity directed against the cell. The special glass tube mentioned was inserted in the path of the light beam. A milliammeter measures the current output of the cell, which varies inversely with the color intensity, and a rheostat in the circuit is used to adjust the setting of the meter reading, which for this test was 100 for clear water. As the color intercepts the light beam, the deflections of the meter decrease proportionately.

TABLE 1

Data and Results of Acceptance Test

Aqueduct id. (average measured), *in.*	64.79
Aqueduct cross-sectional area, *sq. ft.*	22.895
Distance between observation stations, *ft.*	7,533.1
Travel time of color slug, *sec.*	1,184.1
Average velocity, *fps.*	6.36
Flow, *cfs.*	145.66
Flow, *mgd.*	94.14
Additional cooling water flow, *mgd.*	0.38
Total pumping rate, *mgd.*	94.52
Total pumping rate, *cfs.*	146.24
Total dynamic head, *ft.*	438.2
Water horse power, *hp.*	7,269.8
Input to pump, *bhp.*	8,202.0
Efficiency of pumps, *per cent*	88.64
Guaranteed efficiency, *per cent*	87.0

Water was discharged continuously from the center of the aqueduct through a ½-in. pipe inserted through a stuffing box and a flexible rubber hose leading to the glass tube in the "Photelometer." The arrangements for each station were exactly alike, and, because of the distance and the time lag between observation points, the instrument could be transported and used at both.

A watch was placed beside the milliammeter, and both were photographed, during the interval the color was visible, at the rate of 6 or 7 exposures in 10 seconds by means of a "Graflex Recorder" using 35-mm. film.

Meter readings were plotted against time to an exaggerated scale and the exact time between the moments of greatest color intensity at the two observation points determined. It was wondered whether the point of highest color intensity or the centers of gravity of the color curve should be used in determining the time of travel, but there is very little difference between the results obtained by these methods.

Pumping heads were measured by means of mercury manometers connected to the piezometer rings near the suction and discharge of both pumps. Manometer and power readings were taken at frequent intervals throughout the color-velocity observation period and average values were used.

Table 1 summarizes and illustrates the type of data and results obtained by this acceptance test, and Fig. 2 summarizes the result obtained in flow-friction measurements for the composite pipeline—that is: 61-, 63-, and 65-in. pipe.

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2. SCOBEY, FRED C. The Flow of Water in Riveted Steel and Analogous Pipes. U.S. Dept. Agric. Bul. 150 (Jan. 1930).

Developments in Pumping Practices

By H. R. Cady

A paper presented on Nov. 8, 1946, at the New Jersey Section Meeting, Atlantic City, N. J., by H. R. Cady, Mech. Engr., Hackensack Water Co., New Milford, N. J.

ALTHOUGH driving pumps provided one of the earliest uses of steam, the first direct-driven steam pump was built only about one hundred years ago. For the fifty years following, the steam pump developed slowly with the steam engine and took on some of the improvements that were being made in engines. Design and construction of the water end or pump proper were improved, but there was no basic change. Speeds remained low, due, among other reasons, to the difficulty of operating pump valves at high speeds.

Shortly after 1900, however, steam pumping engines reached their peak of development in the vertical triple-expansion crank and flywheel type. In large capacity units, these were magnificent and impressive pieces of equipment. Their efficiency was high and their capacity range wide, running from full capacity to less than one-half capacity while maintaining nearly full load efficiency. The less desirable characteristics of these pumps were their high cost, the expensive housing required by their extreme height and the time required for installation or major repairs. Also, efficiencies decreased with size, and very small units of this type were not practicable.

All types of steam pumps which came into general use during this period of development had in common a very long useful life when they were properly maintained. This characteristic had advantages and disadvantages. One advantage was slow depreciation; a disadvantage was reluctance of owners to make replacements when more efficient pumps were produced.

Centrifugal Pump Developments

The only really basic development in the pump proper, since the invention of the direct-driven steam pump, occurred in the first 15 years after 1900. During this period the centrifugal pump, though invented some years earlier and used in a limited field, was developed rapidly for higher heads and increased speeds with much improved efficiency.

During this same period, steam turbines had developed rapidly and were largely superseding engines for generating electric power. Electric motors were also going through a period of development and improvement. Consequently the centrifugal pump, with its low cost, small space requirement and relatively high rotative speed, was a natural complement to the newer types of driving equipment. As efficient speeds of steam turbines are too high for satisfactory pump speeds, reduction gears have usually been necessary.

Since, about 1912, therefore, although a few steam pumping engines were built, the principal selection of new pumping units for general water supply service lay between steam turbine-driven centrifugal pumps and motor-driven centrifugal pumps. At first, multi-stage pumps were favored for the higher heads, but these soon gave way to single-stage double-suction types, connected in series if necessary. The inherently lower efficiency of smaller capacity steam turbines produced a natural trend toward the motor-driven pumps in the smaller sizes.

Diesel and Gasoline Engines

Diesel engines, which developed rapidly after 1920 to modern, vertical types, have since been used to some extent for individual centrifugal pump drives. For fairly high heads, their speed was somewhat low and step-up gears were usually required. One advantage of the diesel engine is the high efficiency of small units. Another application of the diesel engine is for generator drives where several small pumps are required and purchased current is not available or rates are unsatisfactory.

Occasionally, where natural gas was available and where special local conditions favored their use, gas engines and hydraulic turbines have been used to good advantage as centrifugal pump drives.

As driving units for centrifugal pumps, gasoline engines have been used to a considerable extent since about 1920. The greater number of such units were used for intermittent or stand-by service, but in later years in some instances they have been used for practically continuous service with surprisingly good results. The particularly favorable characteristics are low cost, small space requirement and speeds adaptable to direct connection. Heavy-duty or industrial type engines, with a capacity considerably in excess of pump load under any head condition and adequate cooling capacity, give satisfactory results. They are generally considered to be the logical stand-by units for an electric or diesel station.

Deep-Well Pumps

While the development of the centrifugal pump with various driving units and its application to general pumping requirements was going on, development of the centrifugal deep-well pump was also proceeding. This development was much accelerated when satisfactory ball thrust bearings came into use. For centrifugal deep-well pumps, the motor drive was always predominant, special types being developed to complement the pump designs. In this field, the useful life of pumping equipment has not been so characteristically long as that of standard water supply pumps. This fact, coupled with increasing efficiency of new designs, low cost and ease of installation, has favored fairly early replacement of older types, such as air lifts and bucket displacement pumps, which, due to the low efficiency of the former and the limited capacity of the latter, were rather unsatisfactory. Consequently, in old well fields, equipment has been modernized more quickly than in most surface supply pumping stations. Also, the development of new underground supplies has been greatly accelerated by the advent of the modern deep-well pump.

Pump Design

In the early days of the centrifugal pump, characteristic curves gave interesting test data but were merely incidental so long as the pump delivered

its specified capacity at the specified head. As the designs improved and the art of building pumps advanced, characteristic curves have come to be set up in advance to give as far as practicable the most advantageous results under the usual variations of actual operating conditions. For instance, the motor-driven centrifugal pump supplying a closed system where a nearly constant pressure is desired should have a relatively flat head capacity curve, so that a considerable increase in demand will be satisfied with a small drop in pressure while a reduced demand will not cause an excesive increase in pressure. In deep-well pumps, the drawdown curve can be so related to the head capacity curve as to maintain stable water table conditions.

For centrifugal pumps as well as all types of driving equipment, the past 25 years has been a period of consistent improvement in design and construction. Pump efficiencies have constantly improved. Ball bearings have come into use on many pumps and motors. Turbine blading is better standardized. Motor starting characteristics and starting equipment have been improved. Motors of a capacity several times greater than any available 25 years ago are now frequently used in water supply operation. Turbine speed control devices to maintain constant pressure in discharge lines have been developed. Discharge line control, to avoid back flow or water hammer on starting and stopping pumps, has been developed and improved. With the exception of some parts of well field equipment, centrifugal pumps and driving equipment still retain the characteristic of a long useful life.

In considering water supply pumping practice, it is difficult to make general statements about what is good and what is not. Service requirements, source of water supply, local conditions of existing plant, available electric service, fuel supply, labor conditions, financing and many other factors all have their bearing. The result is that every pumping plant must be largely tailor-made, and most of the pumping units designed or assembled to fit particular needs.

In following the demands of service, it is usually good practice to discard older pumping units still usable but of poor efficiency or small capacity and to replace them with new units. Occasionally, however, pumps which have become practically obsolete due to high first costs or development of new types, may be highly efficient, reliable and economical to operate. At times combinations of steam, electric and other driving power are logical and practical developments.

Recent Developments

The principal recent developments in available equipment appear to be:

1. Magnetic drives for variable pump speed from constant-speed motors.
2. Hydraulic couplings for variable pump speed from constant-speed motors.
3. Automatic control of motor-driven pumps covering combinations of water elevation or pressure, unit selection, timed operation and various other factors.
4. Remote centralized control of various scattered motor-driven units in a system supplemented by telemetered indications of pressure, water level and other factors.
5. Automatic pump-priming device combinations.

6. Application of motor-driven vertical shaft bottom suction centrifugal pumps or various types where rather high discharge head and variable suction conditions exist.

Magnetic drives and hydraulic couplings are adaptations from the automobile field that have been applied in sewage pumps. The principal objection seems to be rather high cost.

The increasing application of automatic and remote controls is a logical development for isolated high area booster stations, well fields, or other conditions under which several small remote pumping units require centralized control. Neither method of control is new, but the connection and mounting of the various devices and elements have been improved and better standardized. For long distance control, telephone wires are usually leased. Automatic controls and remote indication of pressure or water level are sometimes a good practical combination.

Automatic priming devices have the advantage of being packaged units designed for various size and condition ranges. Sometimes they are a necessary complement to automatic or remote control.

The application of vertical pumps to various water supply uses is an adaptation of a combination of deep-well, sewage and drainage types to another field. This development, due to ease of mounting, wide range of capacity, good efficiency and other advantages, promises considerable application to future problems.

During the war years, 1942–45, the principal effort of pumping plant operators lay in maintaining existing equipment in good condition to carry the increased loads required. In some cases, minor additions of emergency units were necessary, but few normal new projects could be carried out, and repair parts and material were obtained with difficulty.

Now, in the postwar period, well-developed pumping equipment of all types and sizes may be found for application to any reasonable pumping requirements. Deliveries may still be slow, but designs, manufacturing facilities and the well-known "know-how" are ready when materials are a little more plentiful and labor conditions somewhat stabilized.

The most difficult problems are now the development of individual pumping plants in such a way as to maintain reliable service, discard worn-out or inefficient equipment, make necessary structural and other changes, and add new equipment best suited to present and future requirements. These problems involve many factors and require the best efforts of the water supply management and engineering staffs, as well as the valuable assistance of manufacturers' engineers. Many cost factors have changed drastically since the prewar period, and others now seem unstable. Consequently, it is difficult to predict plant operating costs with any certainty, and it might be more satisfactory, at present, to make only essential additions of pump capacity and defer large-scale alterations and replacements.

From past performance trends, the author believes that we can look forward to similar slow but consistent development of pumping equipment and pumping plants. Improvements of demonstrated merit will be adopted. Gas turbines, jet propulsion, wireless power transmission, atomic power may come into use for driving pumps of existing or as yet unheard-of design, but each new device before adoption will have to pass the old tests of reliability, adaptability and economy.

Economics of Pipeline Protection

By W. R. Schneider

A paper presented on Oct. 25, 1946, at the California Section Meeting, San Francisco, Calif., by W. R. Schneider, Asst. Engr., Bureau of Tests and Inspection, Pacific Gas & Electric Co., Oakland, Calif.

TO a customer, the cost of service at a point distant from the source of supply depends, to an appreciable extent, on the cost of transportation of the commodity, whether by rail, truck or pipeline. This cost is dependent upon the original investment and the cost of maintaining the carrier equipment. In order to make a profit on the service to the customer, and give it to him at a rate that he is willing or able to pay, the maintenance on the carrier must be kept at the lowest economical figure.

Pipe Corrosion

One of the major items of expense in maintaining a pipeline is caused by external or soil corrosion. In some localities, bare steel pipe can be used and a very long pipe life obtained; under other conditions, such as exist in a salt marsh area, pipes have failed in as little as ninety days. Local action due to soil corrosivity can be determined by soil surveys, and the required amount of protection applied to the pipe, but areas that are corrosive because of the long-line currents are more difficult to predict. The areas rendered corrosive by the latter effect may be located by an electrolysis survey during a wet season one or two years after the line is installed. This delay is necessary to permit the pipe wrapping to absorb moisture from the surrounding soil, thereby losing a great part of its electrical resistance (1).

Corrosion coupons, or test plates of steel, are connected to the pipe in the corrosive areas found during the survey, and the pit depth is measured after one year of exposure. From these pit depth measurements, the pipe life can be predicted with a reasonable degree of accuracy, and plans can be made for additional protection if necessary (2).

A record kept of the leaks as they occur will show the trend and make it possible to forecast the number of failures to be expected for several years in advance. Pipe failures due to corrosion will generally take place, once they have begun, at an increasing rate. The total or cumulative number of leaks in any year is usually found to increase as the square or even cube of the time since the first failure.

The cost of repairs of the increasing number of leaks is charged to maintenance, which rapidly increases the annual cost of the line for each successive year.

Types of Protection

The increasing annual cost of maintenance can be lowered by reducing or eliminating the leak repair portion of the maintenance charge, if one of the following remedial measures is taken:

1. Relocating the line.

2. Installing insulating couplings at certain optimum locations.

3. Reconditioning and rewrapping or double-wrapping the line.

4. Applying electric (or cathodic) protection.

The cost of the additional protection, such as wrapping or electrical equipment, is added to the original cost of the line as part of the investment, and the labor of installing this additional protection is charged to the maintenance account. This additional expenditure, which will reduce the leak repair portion of the annual maintenance charge, can be considered as a delayed payment, or final installment, on a corrosion-proof main. These four methods of reducing pipeline corrosion are applied as follows:

1. *Removing the line to a new location.* An underwater crossing may be raised to a trestle or installed on a bridge, or a line crossing a swamp may be relocated on the higher ground surrounding the swamp. This is practically equivalent to installing a new line if it is too costly to salvage the original line.

2. *Installing insulating couplings at certain optimum locations.* Corrosion due to long-line current can generally be reduced by the installation of insulating couplings placed on the banks on each side of a stream or marsh. This method does not eliminate self-corrosion and may not always completely eliminate the effects of the long-line currents, since the insulating couplings are partially by-passed by the conducting soil in contact with them.

Insulating couplings are only effective when placed at the fixed boundaries between wet and dry soils, such as on river banks and shore lines. Insulating couplings are not effective in irrigated farms or orchard lands, different parts of which are flooded at different times during the year. Under these conditions, the corrosive areas shift so that no fixed location can be found which will permit the use of an insulating coupling.

3, 4. *Reconditioning, rewrapping, or double-wrapping, and electric protection.* For irrigated areas, long continuous welded lines in open country, and city mains, the two foregoing methods are of no avail in reducing corrosion. Under such conditions, pipes are given protection by wrapping, double-wrapping or the application of electric protection. The type of protection to be applied is determined by the cost of application and the resultant annual cost.

The excavation of a line in open country for repairing and rewrapping requires a considerable amount of labor and the use of ditching machines, hoists, and welding, wrapping and other equipment. If the pipeline is in a city or under paved roads, considerable repaving may also be required, with consequent interference to traffic and possible loss of public good will.

If electric protection is applied, very little excavation will be required, but a suitable location must be obtained for a ground electrode, and electric power must be available. All nearby underground structures must be taken into consideration to avoid the possibility of cathodic protection interference. Such interference would cause leak failures on the foreign lines if they are not properly protected.

Annual Charges

Whether a deteriorating line is to be protected by wrapping, double-wrapping or the application of elec-

trical protection is usually determined by comparing the resulting annual costs of the methods. The various items included in these annual cost estimates for pipe that is single-wrapped, double-wrapped or electrically protected may be illustrated by examples. The cost of a mile of 20-in. single-wrapped pipe, assumed to have been laid in open country and to have reached a state of deterioration at which remedial measures are considered imperative, is analyzed in Table 1. In a densely populated area, pipe will not, of course, be permitted to reach the advanced stage of deterioration represented by the assumed eight failures per year.

TABLE 1

Cost in Place of 1 Mile of 20-in. Single-Wrapped Pipe

INVESTMENT	
Total cost of line in place	$35,000.00
ANNUAL CHARGES	
Interest on investment at 6%	$ 2,100.00
Taxes at 1½% of investment	625.00
Depreciation charges	
25-year life at 6%: sinking fund	638.00
Total annual charge on line requiring no repairs	3,363.00
Pipe repairs during past year, Eight at $200	1,600.00
Total annual charge, including repairs	$ 4,863.00

The values shown are only illustrative, of course, for specific estimates will differ widely, depending upon local conditions, including ordinances and state regulations, and the accounting policies of the utility. Depreciation charges on the investment result primarily from wear due to corrosion, obsolescence, inadequacy and demands of public authorities. The amount of depreciation may be determined either by a table or by calculation from the equation:

$$A = D\frac{i}{(1+i)^n - 1}$$

In this equation, A is the annuity to be set aside each year to pay off a debt at the end of n years, D is the original investment minus the salvage value, i the annual interest rate and n the number of years over which the debt is amortized.

Table 2 shows that, when such a line is repaired and given a second layer of wrapping over the original covering, the capital account is increased by the cost of the material applied and the labor is charged to maintenance. Labor costs are not added to capital as they are not salvageable. They may, however, be charged to the maintenance of an entire system, thus reducing the cost per mile, or may be amortized on the sinking fund basis over the life of the pipe, as shown in Table 2. Depreciation

TABLE 2

Cost of Pipe Repaired and Given Additional Wrapping

INVESTMENT	
Total cost of line in place	$35,000.00
Material in second layer of wrapping	528.00
Total investment	$35,528.00
ANNUAL CHARGES	
Interest on total investment at 6%	2,132.00
Taxes at 1½% of total investment	533.00
Depreciation charges on investment at 6%: sinking fund	648.00
Amortization of labor cost of applying extra wrapping to line: $24,472 for 25 years at 6%: sinking fund *	446.00
Total annual charge	$ 3,759.00

* Can be considered as a maintenance charge distributed over a 25-year period.

charges are then calculated as for a new line, beginning with the date of the reconditioning.

The cost of electric protection is shown in Table 3. From the data

TABLE 3

Cost of Pipe Repaired and Given Electrical Protection

INVESTMENT	
Total cost of line in place	$35,000.00
Cost of electrical protection equipment service line and ground electrode	1,500.00
Total investment	$36,500.00
ANNUAL CHARGES	
Interest on total investment at 6%	2,190.00
Taxes on total investment at 1½%	547.00
Depreciation charges on total investment over 25 years at 6%: sinking fund	665.00
Amortization charges on $500 ground electrode; 10 years at 6% *	38.00
Power cost for electric protection per year	135.00
Total annual charge	$ 3,575.00

* Usually charged to maintenance.

thus assembled, it can be seen that the annual cost of a new line requiring no repairs will be $3,363; and of the same line when the rate of failure has increased to eight per year, $4,863. If the cost of a second layer of wrapping material, as added to the original cost of the line and the labor for reconditioning and rewrapping, is amortized over 15 years at 6 per cent, on the assumption that pipe failures may again become a serious problem, the annual cost will be reduced 22 per cent to $3,759. If electrical protection is applied and no further pipe failures occur, the annual cost will be reduced 26 per cent $3,576.

When conditions permit the application of electric protection to a pipeline, the reduction of the annual cost will generally be greater than that which could be obtained by reconditioning and double-wrapping the line.

The amount of the various items enumerated will depend on local conditions, such as corrosivity of the soil, location, distance from source of supply of repair material, labor costs, accounting policies of the corporations with respect to distribution of repair charges, the requirements of public authorities such as the ordinances of cities and counties, and the rulings of the utility commissions of the various states.

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Some Economic Aspects of Softening

By William U. Gallaher and H. F. Weckwerth

A paper presented on Nov. 16, 1946, at the Wisconsin Section Meeting, Green Bay, Wis., by William U. Gallaher, Plant Supt., Water Dept., Appleton, Wis., and H. F. Weckwerth, Mgr., Elec. & Water Depts., Kaukauna, Wis.

SUCH benefits and savings as may be derived from municipal water softening have been described in numerous publications in the past (1). There are numerous factors, however, which must be taken into account when a municipality decides to soften its water. Often troubles are encountered which the water works man may not anticipate.

Carbonate Hardness

One of the first considerations in planning a softening plant is that of the amount and character of the hardness in the water that is to be softened. Carbonate hardness, which is due to the presence of the bicarbonates of calcium and magnesium, can be removed more cheaply by lime treatment than by any other method. Lime treatment involves the use of sedimentation basins, filters and other equipment, and introduces the problem of the disposal of lime sludge. The clarification of turbid waters can be combined with lime softening with only a small increase in capital and operating expenditures over that required for clarification alone. The additional cost will be for lime and the equipment for handling plus the cost of fuel for recarbonation.

There is a limit, however, to the amount of turbidity that can be removed by the lime process. If turbidities are extremely high, clarification prior to lime treatment has been suggested or, at times, special coagulants may be used. If clarification before softening is required, lime treatment loses part of its simplicity.

An incidental advantage to lime treatment derives from the bactericidal action of the lime, especially if it is added in excess. This furnishes a factor of safety which may be sufficient to make a water of questionable purity safe for drinking.

The municipal water clarification plant at Appleton, Wis., was converted into a softening plant and has been softening the city supply by the lime process since September 1942. Prior to that time, Fox River water had been clarified by coagulation with alum and by sedimentation and filtration. Softening was incorporated in the plant along with other improvements, such as a new clear well and a chemical house. The additional equipment required for softening consisted of two lime-feed machines, two large steel tanks for bulk storage, pneumatic unloading equipment and recarbonating equipment. One of the proprietary types of sludge blanket equipment was installed for softening instead of the settling basin originally proposed for clarification. The total

additional expenditures which could be charged only to softening were about $20,000, or about 10 per cent of the total cost of the expansion program. Operating expenses due to increased chemical costs have been increased about $4,000 per year, or about 14¢ per capita per year. The tap water has a hardness of about 68.5 ppm., or about 40 per cent that of the unsoftened water. This amount of softening has not drawn any noticeable amount of favorable comment from the public.

Sulfate Hardness

Sulfate hardness, which is due to the presence of sulfates or chlorides of calcium and magnesium, is more costly to remove by the lime method than carbonate hardness. Soda ash together with lime is required for its removal, and salt is required for the removal of both sulfates and carbonates in the zeolite method. Both soda ash and salt are more expensive than lime, but salt costs are usually less than soda ash plus lime for the same amount of sulfate hardness removed. Moreover, the use of soda ash complicates the chemical treatment of the water by the lime process. Therefore, waters high in carbonate hardness and low in sulfate hardness can be economically softened by the lime method, whereas waters high in sulfate hardness and low in carbonate hardness may be most economically softened by the zeolite method. Other factors, however, such as plant size or sediment, will have an important bearing on the type of softening adopted.

In the Kaukauna area, the hardness of the ground water increases with well depth, although the carbonate hardness remains almost constant. In other words, the increase in hardness is due almost exclusively to increase in sulfate hardness (Fig. 1). As this clear well water is high in sulfate hardness and low in iron, the zeolite method is the most practical method of softening it. Moreover, any possible increase in hardness as the well is used will be in the form of sulfate hardness, which would make the zeolite method even more advantageous than it is at present.

The city of Kaukauna recently increased the capacity of its well supply, and, in view of the fact that the hardness of its ground water increases with depth, it was decided to limit the depth of the wells to 550 ft. Two new wells

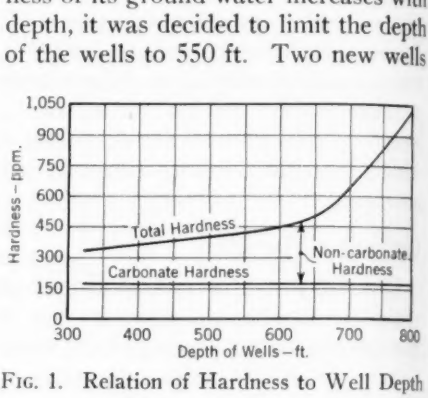

FIG. 1. Relation of Hardness to Well Depth

have recently been drilled to that depth and one old well 733 ft. in depth is to be filled to the 550-ft. level. By this procedure, water of 377 ppm. hardness will be obtained in place of the present water, which contains 702 ppm. hardness. Based on 1944 figures, the cost of softening the present supply from 702 ppm. to 86 ppm. was estimated at 5.69 and 7.56 per 1,000 gal. respectively for fixed charges and salt costs. The cost of softening water from 428 ppm. to 86 ppm. was estimated at 6.67 and 4.20¢ per 1,000 gal. respectively for fixed charges and salt costs. Using the softer raw water (428 ppm.) would effect a saving of 2.38¢ per 1,000 gal. This amount is

sufficient to pay for the additional wells and intermediate piping in a period of three years. It is more economical to bring the water from the three wells to a central location than to soften the water at each well.

Incidentally, it should be mentioned that, as the importance of fluorine has been recognized in recent years, the content of fluorine should be considered in choosing a source of water. The cost of adding fluorine per part per million is about $1.30 per mil.gal. Kaukauna water has a fluorine content of 1.8 ppm.

Industrial Consumption

Softening has a bearing on the uses to which a water is put beyond the savings in soap for washing purposes. Industries as well as householders benefit from softening, yet most industrial managers, looking at the problem from the profit standpoint, do not wish to admit that the benefits derived from softening are sufficient to justify a raise in water rates.

The proportion of industrial to other consumption varies widely among cities. For example, during 1945, at Menasha, Wis., 81.5 per cent of the total consumption was industrial; at Kaukauna, Wis., 51.3 per cent; and at Appleton, 40.8 per cent. It is questionable whether the cost of softening of the total water supply at Menasha, which has a 154 ppm. hardness at present, would be compensated for by the savings in soap to the domestic consumers, who use less than 20 per cent of the water. It must be borne in mind, however, that increases in rates to pay for the cost of softening will fall on the industrial users as well as the domestic customers who receive the greatest benefits from the softening. If the industrial customers are carrying an appreciable portion of water department costs, care should be taken that rates are not raised so high that industries will switch to some private supply.

Objections to Soft Water

It is a well-known fact that soft waters will corrode iron pipes and fixtures more rapidly than hard waters, especially if oxygen is present and the water is heated. Corrosion is especially noticeable in hot water tanks in which the temperature exceeds 150° F. Hard waters will form scale, but the scale protects the metal from corrosion, so that rust is not discharged. Moreover, surface waters frequently contain organic matter which assists in the protection of the metal. This organic material is removed by the softening process, and the water becomes more corrosive. Much work is being done to solve this problem. At present, the householder is told not to raise the temperature of the water above 140 to 150°F. This may require the installation of larger storage tanks and controlled heating in order to obtain sufficient hot water.

Another objection to lime-softened water is the high pH frequently carried in the finished water. Paper mills, which represent the chief industry in the Appleton and Kaukauna area, desire a water with a pH near the neutral point of 7.0. Although the higher pH water is softer and better for their work than a neutral water of high hardness, most paper mill operators desire the lower pH water. This prejudice is not as strong as it was some years ago, because mills have since used the high pH water with success.

Home Water Softeners

The rapid spread of commercially serviced home water softeners in recent years is of vital interest to the municipal water works man. These companies contract to furnish soft water on a monthly or a weekly basis by installing the softener and thereafter replacing expended units or expended mineral. The cost to the householder for this service varies at different communities. One company in the Fox River area charges $2.25 per month with regeneration every 28 days. If changes are required more frequently than 28 days, an additional charge of $1.00 per month is made. Whether the softener is installed so that the entire house supply or only the hot-water supply is softened is optional with the householder.

If the municipal supply contains dissolved oxygen, the water works man may expect some complaints of rusting in hot water tanks following the installation of these units. As the change in the water is made on the customer's premises, however, the municipal supply can scarcely be held responsible. The householder should be told to keep temperatures down to 140°F. to minimize the trouble, although there will probably be more corrosion than is caused by the 68 to 86 ppm. of hardness remaining after municipal softening. It is of interest that when hot water only is softened to zero hardness, the resulting mixture of soft hot water and hard cold water used in the household has a hardness as high as, if not higher than, a municipally softened water of 28 to 86 ppm.

Olson (2) states that when water is reduced from 51 ppm. down to zero hardness, the savings may be as great as the savings when a supply is softened from 510 down to 51 ppm. of hardness. Most municipal softening plants reduce hardness to 51–86 ppm. only because some calcium carbonate is desirable for the protection of steel and iron from corrosion. Since the removal of the last 51 ppm. doubles the savings, the commercially serviced home softener installed in the line to the fixtures where soap is used may be the most practical method of softening municipal waters of up to 342 ppm. of hardness. The higher the industrial consumption and the lower the initial hardness, the greater would be the advantage of household softeners. When the softening is done in the home, the householder would not object to the installation of corrosion-resistant piping as much as he would if the water were centrally softened. Several municipal water works are operating removable zeolite units in their own cities. It must be remembered that, once a municipal water works institutes household softening, it will be difficult to discontinue that service. Softening is chiefly a matter of economy, however, and the city need not take on this responsibility so long as the field is competitive.

The softening of a municipal water may, in short, be likened to the installation of gadgets and mechanical improvements in an automobile. These accessories add to the comfort and satisfaction of the owner, but they increase the possibility of something going wrong and call for greater maintenance efforts and skill.

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Treatment Plant Operating Costs

By Kenneth V. Hill

A paper presented on Nov. 15, 1946, at the Wisconsin Section Meeting, Green Bay, Wis., by Kenneth V. Hill, Partner, Greeley and Hansen, Cons. Engrs., Chicago, Ill.

TO prepare an analysis of the cost of operating water treatment plants involves great difficulties, due mainly to the lack of uniformity found in the reports of water departments. Unrelated costs, such as those of supervision and heating, are usually grouped together, as are the costs of labor, power, maintenance and repairs for both pumping and filtration.

Except for large plants, plants in which union rules require separate pump and filter attendants, or filter plants which are located distant from either or both low- and high-lift pumping stations, the filter plant operators also operate the pumps. To divide the labor costs between filtration and pumping is difficult and would serve no useful purpose. Hence, such a division is not usually made.

Factors Affecting Costs

In general, most published reports contain much more detailed information on costs associated with meters, mains and services than they do on the cost for purification. Among the factors having a considerable effect upon purification costs are:

1. The quality of the source.
2. The location of the intake.
3. The plant capacity.
4. The quality of the plant design.
5. The skill and attentiveness of the plant operators.

In the data on operating costs which follow, an attempt is made to illustrate the effect of each of these items upon the cost for purification. Data on operating costs are presented for three general types of sources of supply: the Great Lakes, rivers and impounding reservoirs.

Among source of supply factors, water quality exerts the greatest influence on the operating cost. The extreme range of turbidities, alkalinities and pH values which may occur in river supplies, as well as the pollution of the water by industrial wastes, requires frequent changes of chemical dosages and sometimes the use of expensive corrective measures. By and large, rivers are more subject to change and pollution than are lakes or impounding reservoirs, although there are a few notable exceptions to this rule.

A carefully designed intake and a judicious use of the arrangements provided by the designer for withdrawing water from various levels will influence the cost of operation. This is true of river intakes, where there is likely to be shifting sand, and of impounding reservoir intakes, where manganese may be a problem.

In general, adequate capacity of plant will lower operating costs due to the greater displacement periods available in the mixing and sedimentation basins. The improved efficiencies

TABLE 1

Operating Costs at Plants Treating Great Lakes Water

Plant	Source	Year	Quantity Treated		Annual Operating Cost					Cost per mil.gal
					Chemicals	Personnel	Maintenance, Repairs, and Supplies	Miscellaneous	Total	
			mil.gal.	*mgd.*						
A	L. Michigan	1940	207.3	0.57	$ 706.81	$ 816.67	—	—	$ 1,523.48	$ 7.36
		1941	229.7	0.63	722.55	946.04	—	—	1,668.59	7.30
		1942	212.7	0.58	749.19	866.59	—	—	1,615.78	7.60
		1943	243.0	0.67	848.86	743.64	—	—	1,592.50	6.55
		1944	284.6	0.78	868.07	1,107.70	—	—	1,975.77	6.95
B	L. Michigan	1940	790	2.16	—	—	—	—	17,854.00	22.60
C	L. Michigan	1945	1,592	4.36	6,528.31	6,943.49	$ 4,794.19	$ 579.26	18,845.25	11.90
D	L. Michigan	1940–41	1,404	3.85	2,834.04	28,176.00	4,557.04	2,057.73*	37,624.81†	26.90
		1941–42	1,632	4.47	3,201.55	29,276.00	5,597.46	2,045.41	40,120.42	24.60
		1942–43	1,679	4.60	3,686.39	29,208.30	5,223.89	2,562.66	40,681.24	24.30
		1943–44	1,976	5.42	4,758.74	34,010.34	6,562.06	1,911.56	47,242.70	24.00
		1944–45	2,153	5.90	5,362.99	31,401.92	8,308.28	1,811.40	47,809.11	22.20
E	L. Michigan	1940	2,743	7.50	—	—	—	—	27,923.23	10.20
		1945	4,278	11.70	—	—	—	—	46,716.68	10.90
F	L. Erie	1940	9,129	25.0	5,843.43	31,561.82	1,530.27	2,139.59	41,075.11	4.50
		1943	11,747	32.1	9,673.81	41,302.77	1,375.96	1,693.76	54,046.30	4.61
		1944	12,095	33.2	9,940.48	41,021.58	1,274.94	2,084.46	54,321.46	4.50
G	L. Erie	1944	17,995	48.4	65,226.17	63,562.50	34,735.17	14,287.32	177,811.16	9.89
		1945	17,292	49.0	49,256.59	63,336.83	32,622.31	15,653.58	160,869.31	9.30

* Heating.
† Cost for power excluded.

of these units will lessen the amount of coagulant required. Also, lower filtration rates permit longer runs between backwashes, thereby increasing the net yield from the raw water.

Economical operation is much more likely in a properly designed plant than in one built by an inexperienced designer. Waters have such varying characteristics that no single design can be standardized and used for all conditions. A poor design will increase the cost for chemicals, maintenance and repairs, and power.

The operator is required at all times to keep a careful watch on coagulant dosage, filter backwashing, disinfection, pump performance and other aspects of plant operation too numerous to mention, if the plant is to be economically operated. Improper coagulation is not only wasteful of chemicals, it may also increase maintenance costs if a corrosive or encrusting water is produced. Improper backwashing can affect the net yield from the raw water. Improper disinfection may produce an unsafe or an unpalatable water. A small piece of wood implanted in the eye of an im-

TABLE 2

Analysis of Operating Costs of Three Plants

Plant	Chemicals	Personnel	Maintenance and Repairs	Miscellaneous
	per cent	*per cent*	*per cent*	*per cent*
D	9.1	71.6	14.0	5.3
F	16.8	76.1	1.9	5.2
G	34.0	37.5	19.9	8.6

peller can reduce the capacity and the efficiency of a centrifugal pump.

Plant Operating Costs

Great Lakes Supplies

Seven plants treating water from the Great Lakes have been selected for discussion, five treating water from Lake Michigan and two treating water from Lake Erie. All are rapid sand filtration plants, and none of the plants has been operated above its nominal rated capacity. The production of the plants ranges from about 0.5 to 49.0 mgd.

Information on operating costs is summarized in Table 1. An attempt has been made to arrange the data in the ascending order of plant production, for it is to be expected that, as the production increases, the unit cost per million gallons would decrease. For one special reason or another, however, this relationship does not hold for the examples cited.

Plant A is unusual because, except for three months in the summer, it is operated only from six to eight hours per day. An unusually large amount

TABLE 3

Operating Costs at Water Treatment Plants Treating River Water

Plant	Source	Year	Quantity Treated		Annual Operating Costs					Cost per mil.gal.
			mil.gal.	*mgd.*	Chemicals	Personnel	Maintenance, Repairs, and Supplies	Miscellaneous	Total	
H	Wisconsin R.	1940	253.4	0.69	—	—	—	—	$ 8,102.54	$32.10
		1945	288.6	0.79	—	—	—	—	9,453.36	32.80
I	Mississippi R.	1940	1,080	2.95	$15,712.44	$14,195.45	—	$1,688.09*	31,595.98	29.25
		1945	1,389	3.81	17,921.19	21,664.85	—	1,213.70	40,799.74	29.50
J	Tennessee R.	1944	6,191	17.0	55.00	641.32	$6,309.57	—	61,950.89	10.00
K	Missouri R.	1944	14,030	38.4	—	—	—	—	109,714.60	7.82
		1945	14,158	38.8	—	—	—	—	95,849.66	6.77

* Laboratory, supplies, and heating.

TABLE 4

Operating Costs at Water Treatment Plants Treating Water from Impounding Reservoirs

Plant	Year	Quantity Treated		Annual Operating Costs					Cost per mil.gal.
		mil.gal.	*mgd.*	Chemicals	Personnel	Maintenance, Repairs, and Supplies	Miscellaneous	Total	
L	1943	687.9	1.88	$2,749.17	$ 9,474.62	$1,438.33	$368.25	$14,030.37	20.40
M	1944	910.0	2.48	4,590.00	8,167.00	364.00	—	13,121.00	14.40
	1945	940.0	2.58	4,781.14	11,245.00	551.09	—	16,577.00	17.60

of elevated storage and excess filter capacity permits this schedule of operation. The very low personnel cost is to be noted.

Plant B is probably representative of normal raw water conditions.

At Plant C the raw water is normal, but the process requires heavy chlorination because of sewage pollution.

At Plant D it was impossible to separate the personnel responsible for pump operation.

Plant E represents normal operation; the cost for pump operating personnel is included.

TABLE 5

Great Lakes Plant Personnel Costs

Plant	Year	Quantity Treated	Personnel Cost	
		mil.gal.	Total	Cost per mil.gal.
A	1944	284.6	$ 1,107.70	$ 3.90
C	1945	1,592	6,943.49	4.38
D	1944–45	2,153	31,401.92	14.60
F	1944	12,095	41,021.58	3.40
G	1945	17,292	63,336.83	3.54

The data for Plant F appear to be somewhat out of line, especially when they are compared with the data for Plant G. A very favorably located intake at Plant F furnishes a water of low turbidity which requires only 4.3 ppm. of alum for coagulation. Chlorine consumption, however, is high.

At Plant G the intake is in relatively shallow water and is also subject, under some wind conditions, to pollution from a river. Four times as much alum is required at such times, and, in addition, 8.6 ppm. of lime is required for coagulation. The cost for maintenance, repairs and supplies is high. Distribution of operating costs for Plants D, F and G, expressed as percentages of the total operating costs, is shown in Table 2.

TABLE 6

River Plant Personnel Costs

Plant	Year	Quantity Treated	Personnel Cost	
		mil.gal.	Total	Cost per mil.gal.
I	1940	1,080	$14,195.45	$13.10
	1945	1,389	21,664.85	15.60

River Supplies

Data on operating costs of four plants treating river supplies are summarized in Table 3.

The water treated at Plant H is highly colored and usually contains considerable taste and odor. The operating costs include the cost for pump operating personnel.

The water treated at Plant I is at times very turbid and always contains considerable taste and odor. Because of the large amount of alum required for coagulation, it is necessary to add considerable lime to adjust the pH of the coagulated water and prevent corrosion.

At Plant J, where water is taken from the Tennessee River, considerable difficulty is experienced with

TABLE 7

Impounding Reservoir Plant Personnel Costs

Plant	Year	Quantity Treated	Personnel Cost	
		mil.gal.	Total	Cost per mil.gal.
L	1943	687.9	$ 9,474.62	$13.70
M	1944	910.0	8,167.00	9.00
	1945	940.0	11,245.00	12.00

TABLE 8

Data on Operating Personnel

Size of City	Pumping Station		Filtration Plant		Station and Plant Combined	
	No. of Men	Total Annual Salaries	No. of Men	Total Annual Salaries	No. of Men	Total Annual Salaries
Under 20,000	1.66	$3,866	2.00	$4,634	3.66	$ 8,500
20,000–50,000	2.57	5,000	2.01	4,400	4.58	9,400
Over 50,000	3.40	7,700	3.00	7,000	6.40	14,700

TABLE 9

Variations in Chemical Costs

Plant	Year	Quantity Treated	Cost of Chemicals	
			Total	Per mil.gal.
		mil.gal.		
Great Lakes				
A	1944	284.6	$ 868.07	$ 3.04
C	1945	1,592	6,528.31	4.11
D	1944–45	2,153	5,362.99	2.48
F	1944	12,095	9,940.48	8.21
G	1945	17,292	49,256.59	2.85
Rivers				
B	1940	1,080	15,712.44	14.50
	1945	1,389	17,921.19	12.85
Impounding Reservoirs				
L	1943	687.9	2,749.17	4.00
M	1944	910	4,590.00	5.05
	1945	940	4,781.14	5.08

tastes and odors from industrial wastes. Sewage pollution is also a factor.

At Plant K the turbidity of the raw water varies from 44 to 7,500 ppm. Three stages of sedimentation are utilized: plain sedimentation, primary mixing and sedimentation, and secondary mixing and sedimentation. Alum is manufactured at the plant.

Comparison of the data in Tables 1 and 3 indicates, in general, that river water is more costly to treat than water from the Great Lakes, at least for the plants selected.

Impounding Reservoir Supplies

There are relatively few impounding reservoir projects in the Middle West where filtration only is practiced. In most plants, regardless of size, the water is also softened. Data on water treatment in two plants are given in

Table 4. The cost for reservoir treatment is included in the cost data. For these two plants the unit operating cost per million gallons is less in the same production bracket than for either the Great Lakes or the river supplies. The data, however, are too limited to yield any conclusions about actual relative cost.

Operating Personnel Costs

The data in Tables 1, 3 and 4 have been utilized to develop the unit costs for operating personnel per million gallons treated. In the Great Lakes plants during 1944 and 1945, these costs varied as shown in Table 5. The same data for the plants utilizing rivers as a source of supply are given in Table 6. The cost for operating personnel at the plants utilizing impounding reservoirs as sources of supply is given in Table 7. It is difficult to draw any conclusions from these data that would be valid, beyond determining that the unit cost per million gallons for operating personnel is in nearly inverse proportion to the quantity of water treated.

In March 1946, A. E. Anderson, Supt. of Water Works at Moline, Ill., made a compilation of the number and salaries of water works operating personnel in 28 cities in Illinois, Indiana and Wisconsin. Some of this information has been presented in Table 8. It will be noted that in cities of less than 20,000 population, the average annual salary of the pumping and purification personnel is $2,350; in cities of 20,000 to 50,000 population, the average annual salary is $2,050; and in cities of over 50,000 population, the average annual salary is $2,300. In most of the cities canvassed, the employees are pensioned upon retirement and are paid for overtime work. Two weeks' annual holiday with pay is general.

Chemical Costs

Table 9 indicates chemical costs per million gallons treated in the plants discussed in this paper. Except for plant F, the chemical costs in the plants utilizing the Great Lakes as a source of supply do not vary greatly. The data show that the chemical costs at plants using river water are greater than at plants using the Great Lakes or impounding reservoirs as sources of supply.

Losses in Distribution Systems

By Dewey W. Johnson

A paper presented on Nov. 17, 1946, at the Wisconsin Section Meeting, Green Bay, Wis., by Dewey W. Johnson, Asst. Engr., Cast Iron Pipe Research Assn., Chicago, Ill.

PROBABLY in no other industry is there so much room for improvement in operating efficiency as in the water industry, and particularly in the average small town municipal water plant. The losses and unaccounted-for water in the distribution system of the average small town represent a needless waste of chemicals, electric power and labor that adds nothing to the economic growth of our cities, states or nation. Many water plants are unable to account for 50 per cent of their daily pumpage, and the majority of well-managed plants, employing better than average personnel, are still unable to account for more than 85 per cent. Certain communities, in which a few properly metered industrial customers consume much of the water, can reduce their percentage of loss to a small amount, but, even so, it is a rare water system that is able to sell 90 per cent of its pumpage.

Most water works superintendents use the phrase "percentage of water accounted for," but a much better phrase would be "percentage of water sold." It has been a custom for superintendents reporting these figures to add an estimated amount to the sales to provide for water used in street sprinkling, sewer flushing, fire fighting and other municipal uses. This estimate, added to the actual sales through the meters, has allowed many superintendents to show a respectable percentage "accounted for," since it is only human nature to make the estimate as large as possible. The figure that really represents the correct efficiency of the plant operation is the ratio of the total water actually sold to the total water pumped.

Efficient Operation of System

The Effingham, Ill., water system is an example of one showing a high degree of efficiency. This plant was able to account for 92 per cent of its pumpage because two carefully metered trunk line railroads pass through the city and often purchase 50 per cent of the total. In another system, in Texas, the superintendent accounted for 93 per cent of his total pumpage; on a visit to that city the author learned that an oil refinery uses almost as much water as all the rest of the customers. These examples of high efficiency can hardly be called typical of American water systems.

Experience has shown that, with efficient operation of a public water system, a plant should sell about 85 per cent of the total water pumped. A water plant is similar in some respects to a foundry. It is impossible to run

a foundry without some breakage; likewise, it is impossible to run a water system without some unaccounted-for losses. On the other hand, what would the president of a large foundry say if 25 to 50 per cent of all the castings manufactured were being lost because of poor workmanship or carelessness of the employees? The profitable operation of a water system is directly related to the unaccounted-for water, just as the foundry profits are related to the number of defective castings. The principal difference, however, lies in the fact that a particular person or group of persons own a foundry for the purpose of making a profit, whereas the public water supply belongs to every customer within the city limits. The management has only a small, indirect interest in the profits or net revenue of the public water supply. Public water supplies (with but one exception—Waukesha, Wis.) have yet to install a bonus system for efficient operation.

Lack of Incentive

Many communities use the water department as a method of collecting indirect taxes. In fact, one community near Chicago recently gave the people a choice of whether they should increase the taxes or raise the water rates, thereby publicly admitting that the water system was used as a means of collecting taxes. It has been a widespread practice for water departments to turn over a large percentage of their gross revenue to the general city tax fund for the operation of the other departments of the municipal government. This practice of using the water department as a taxing agent has dulled the interest of many superintendents in efficient operation of their systems. Why should they devote their time and energy to improving the efficiency of the water department when all of the profit obtained thereby is turned over by the general council for the operation and maintenance of the police or fire department?

Again, the author has heard water superintendents remark, "Why should we go out and look for leaks when we know that it will be our responsibility to see that they are repaired? The council isn't interested in leaks, why should we exert ourselves?" A midwestern superintendent has a leak in a water main underneath a railroad crossing which has been running for over nine years at a rate of 10,000 gpd. He has not repaired this leak because the council has never shown any great interest in leakage surveys or efficient operation of the system and, therefore, provides him with no incentive to take care of this dirty job of working underneath a railroad track with heavy trains operating over it every 30 minutes. But it is worthwhile to set forth some of the reasons why the water systems all over the country are losing so much of their water and are going along so casually with such a high unaccounted-for water loss. The national waste incurred by the poor efficiency in accounting for the water produced by public water supplies may easily be costing this country more than $50,000,000 per year for operation alone, not considering the investment necessary to produce such quantities of water.

Let us assume that the superintendent owns the water plant as a private individual and that he would profit directly by reducing unaccounted-for waste or leakage. Certainly, he would immediately begin making leak surveys, testing meters and making ge-

eral improvements for economy of operation. This is proved readily enough by the fact that the average daily pumpage per capita for 3,000,000 people served by 78 privately owned utilities is only 63 gpd., compared with the 133 gpd. which is considered the average pumpage per capita for the entire country. It would be embarrassing to mention names, but the superintendents of plants near Chicago have stated that their systems were losing 53, 80, 23, 65, 50 and 15½ per cent respectively of the daily pumpage. One community which is buying water wholesale, at a cost of 7½¢ per 1,000 gal., is losing 47 per cent of all it buys. That means about $26,000 per year is lost in a town of 8,000 population because of leaks and poor meters. Another town buying from the same source was selling only 45 per cent of the purchased water.

Reasons for Losses

Where does all of this unaccounted-for water go? There are just two places where water can be lost for revenue: at leaks in mains and services or at meters which are failing to register the proper amounts. This separates the task of improving the efficiency into two divisions: the location and repair of leaks throughout the system, and the proper installation and servicing of meters. One of these may be just as important as the other, although in all probability, if reasonable care has been taken of the meters, most of the waste is being caused by leaks. Table 1 shows the findings of a leak survey conducted in a Wisconsin city. This water department was well managed and, at the time the leak survey was started, was able to sell 83.6 per cent of its pumpage. Further improvements were desired, however, and The Pitometer Co. was employed to locate additional waste. The results in this city showed that most of the unaccounted-for water was slipping through large meters unsuited for the services on which they were installed. The action taken as a result of the survey increased the efficiency from 83.6 to 90.2 per cent, and the percentage has since been increased to 94.5, one of the outstanding records in the country.

TABLE 1

Survey of Leakage in a Wisconsin City

	gpd.	*per cent*
Daily pumpage	5,000,000	100.0
Accounted for by meters	4,180,000	83.6
Unaccounted for	820,000	16.4
Found by Survey		
Losses through large meters	209,000	4.2
Service leaks (80)	118,000	2.3
Leaks in mains (1)	18,000	0.3
Total found	345,000	6.8
Accounted for after survey	4,525,000	90.2

Distribution System Leaks

Leaks in the distribution system may be subdivided into several groups: main leaks, joint leaks, fire hydrant leaks, valve leaks, live service leaks and dead service leaks. Further subdivision may distinguish leaks in iron services, lead services, copper services, wiped joints and service fittings.

The location of leaks in these various parts of the water distribution system may be accomplished by several methods. The simplest and also

the least expensive method of location is by the use of the simple aquaphone. There are on the market several higher-priced leak-finding devices operated either on the radio or the telephone principle, as well as similar apparatus for the location of pipes. With the exception of those using the color method, most types of leak-finding equipment eventually depend upon the sound vibrations created by the water discharging from the hole in the pipe. The more expensive ones are able to magnify this sound several hundred or thousand times; the simple aquaphone does not have this great amplifying power.

The simplest combination of leak-finding methods for small towns employs the aquaphone for service leaks and the sewer inspection method for detecting large leaks, such as broken mains or blown lead joints. There are two distinct advantages in these methods: simplicity and low cost. The ordinary personnel of the system can be used for carrying on this type of a survey; no special college training or engineering study is necessary. The meter readers can be instructed to conduct the survey as they are reading meters, but it would be even better to have the meter readers go over their routes for a second time after the meters are read, just to listen to the services. A house-to-house survey by the meter readers or persons of similar rank of employment, plus a check on the fire hydrants and valves as they are passed along the route, will detect practically all the leaks in the system.

Aquaphone Leak Detection

The aquaphone can readily detect small leaks on service pipes for a distance of some 50 to 150 ft. under ordinary residential conditions. The smaller the leak the higher will be the pitch in the phone, and the distance to the leak can be estimated after a little experience. The weakness of this instrument lies in the detection of larger leaks on the heavier mains which do not emit vibrations as easily as the smaller sized services. Mains and service leaks discharging into a submerged body of water are difficult to hear.

The cost of this type of survey is low. A suburb of Chicago was recently covered by college students at a labor expense of $30 per 1,000 population covered; another suburb reported a cost of $40 per 1,000 covered when paying the operator $2 an hour. The college students located 67 leaks in ¾-in. galvanized-iron service pipe between the service box and the house and 26 leaks in lead pipe between the main and the service box. They also located one leak in a fire hydrant, and reported no leaks in the lead joints or mains. This suburb has been working hard to improve its unaccounted-for loss, and over a 5-year period has raised the efficiency from 50 to 84½ per cent. During this time, the operators have repaired 376 service leaks, 14 fire hydrant leaks, and 2 main leaks. A second suburb, which started a leak survey for the first time during 1944, reported 72 service leaks in a section supplying 4,000 population, or one service leak to every 55 persons. Practically 75 per cent of these were caused by the failure of galvanized-steel services; the other leaks were mechanical failures in lead service pipes caused primarily by poor workmanship of the plumbers or laborers making the installation 15 or 20 years ago.

The first time a survey is conducted, it may be necessary to go over a street two or three times to catch all the leaks with the aquaphone, as the loud leaks will drown out the vibrations of the small ones. The larger leaks should be located first and the smaller ones last. In one survey the author found eight galvanized service pipes that had rusted through in one city block; the aquaphone showed a leak on every service. Under such conditions, part of the work must be repaired before the operator can continue with the aquaphone.

This summer a similar condition was found in a central Illinois town of 1,000 population which was making its first leak survey. The first trip with the aquaphone, by local employees, found 50 leaks; the second trip around, by an experienced aquaphone operator, found so many more leaks that the workmen have not yet caught up with him, and it was decided to stop detection because the vibration from known leaks conflicted with the leaks to be detected. This town was losing 66 per cent of the daily pumpage when the survey started; final results are not yet available. Before the survey, the superintendent thought that he had only one large leak to start with. In order to locate this supposedly large leak, he divided the town into seven districts, and each night measured the loss in one of these sections. This preliminary test showed that leaks were scattered over the entire area and that a large number of small leaks was causing the trouble, not just one large leak.

Inspection of Sewers

After the water system has been covered by a house-to-house survey using the aquaphone and the leaking services so located have been repaired, an inspection of all sewers should be conducted. This inspection will locate any large leaks which were not detected by the aquaphone, and, at the same time, it will aid in the exact location of leaking services. A leak of any consequence throughout the system will do one of two things: either it will come to the surface and be a public nuisance, so that the operating personnel will have to take care of it, or it will find its way into the sewer system. There may be certain areas of the distribution system which are underlain by sand, gravel or cracked limestone. Leaks that occur in such areas are difficult to locate because they do not come to the surface, and, instead of entering the sewer system, may percolate directly into the underground stratum. The color of the vegetation will usually show leaks in sandy soil. An inspection of the sewers may be the easiest way to locate definitely service leaks that have been detected by the aquaphone.

In the past, many cities laid water mains and sewers down the middle of paved streets, extending lead services to service boxes located at the curb lines. Services were installed for each lot, regardless of whether there was a house built on the lot or not. These dead services are a constant source of leakage in a system and are difficult to find because ordinarily the service boxes are not shown on the drawings and do not extend above the ground line, where they will be visible.

An inspection of the sewer will show whether an unusual amount of clear water is being discharged. In fact, it is very easy to check the leakage in a system for 8 or 10 blocks of a residential section simply by looking in the final manhole or the sewer system

draining that area. If the contents of the sewer are clear water, further exploration will show the location of the leak; if the contents are only sewage, no further search need be conducted. The sound of flowing water being discharged into the main sewer from the house lateral sewers can be heard quite distinctly for a considerable distance in the sewers, and if there is a continual rushing of water for longer than a brief time, further study may disclose a leaky service discharging into the house sewer and then to the street sewer with no visible leakage on the ground surface. The sewer method of finding leaks is best employed at night, when domestic consumption is at a minimum. If there is about 50 per cent leakage, however, the method can be used very well in the daytime with excellent results, and a further check can be made at night if necessary. Two mirrors or powerful flashlights will prove of value when inspecting sewers.

Other Detection Methods

After the house-to-house survey has been completed and the sewer inspection conducted, other general points throughout the community where leaks are suspected should be investigated. All points where water mains cross under railroad tracks should be investigated for leakage. The railroads are building larger and larger locomotives all the time, and many of the water mains were installed under shallow covering 40 or 50 years ago, when the railroads were using relatively lightweight locomotives. If mains were laid under rivers, canals or other bodies of water, provision should be made for testing those sections of the lines by placing ⅝-in. water meters around the valves on one side. River crossings are difficult to install and the pipe is subject to settlement or damage by boat anchors. Leaks caused in these ways could never be detected unless such a special test were conducted; several large leaks have been located by this procedure.

The location of springs and swamps should be carefully investigated, especially if there is a water main or service within a reasonable distance. A Chicago suburb recently dried up a large "spring," which had been flowing in a vacant lot for many years, when investigation found a ¾-in. lead service pipe on the lot that had been cut off by some workman's shovel and abandoned. Leaks may also be located in partially developed subdivisions by the vegetable growth of the area. The leaks may be noted by the abundant growth of horse weeds or other rough water-consuming plants.

Cities located in the northern section of the country can use the snow method of locating leaks. This method is usually employed in the fall, when the first light snow falls, simply by driving in a car over the system. Bare spots can be located on the pavements and sidewalks where the leaking service will emit sufficient heat to melt the snow as it falls; the remaining area will be covered with a light sheet of snow (Figs. 1, 2). These spots should be marked and then checked at a later date with the aquaphone, geophone or radio equipment. Care must be used to avoid spots where automobiles have been parked, for the heat radiating from the engine will give the same results.

One superintendent uses the dew and frost method for spotting leaks after their general location has been determined. One of the employees arises in the early hours of the morn-

ing and watches the dew or frost disappear from the pavement and thereby determines where to dig for the leak. Sometimes the use of all of these methods, the geophone and the best of radio instruments will fail to locate the correct spot to break the pavement. Time will usually solve the location of these leaks, as they will seep into basements, come to the surface, undermine the pavement or become large enough to be heard or noticed in the sewer inspection. Leaks will sometimes occur in such a manner as not to set up a vibration in the pipes. These are difficult to locate as the sound devices will be of little assistance. Such leaks may continue for a long time and be found by accident or by complaint from a customer due to poor pressure.

FIG. 1. Leak Indicated by Wet Spot in Snow

Most superintendents report that they have no leaks when what they correctly mean is that they have no visible leaks. Every system has "out-of-sight" leaks, and it is only the efficient superintendent who makes a yearly survey to keep these at a minimum. Galvanized-steel service pipes are a constant source of leaks, requiring an annual inspection. The important thing is to keep the duration, or life expectancy of these service leaks, as short as possible. If they come to the surface, it is short; if they find their way to a sewer, they will have a long life. Water services should never be laid in the same trench with the house sewer, if for no other reason than to avoid undue difficulty in the location of leaks.

Leaks in Large Cities

The size of a city has a relationship to the type of leaks found. A large city will have a larger percentage of joint and main leaks because of the heavy traffic conditions and the building of other subsurface structures adjacent to the mains, whereas in small towns leaks are primarily found in service pipe. Table 2 gives an analysis of the number and types of waste found in cities of various sizes.

FIG. 2. Excavated Service, Showing Leak of 8 gpm. or 11,000 gpd.

The methods of leak detection so far discussed have been mostly applicable to small towns. As the size of the towns or cities increases, more elaborate methods must be used. Radio equipment for locating leaks has proved a great help because of the multiple amplification of the sound vibrations. There are several companies now offering excellent leak finders of this type. Pitometer rods and portable

meters are valuable tools for locating leakage in long stretches of mains of a given section of the city.

Radio Leak Detection

The radio equipment is used in much the same manner as the simple aquaphone except that more miles of mains can be covered per day and small vibrations can be detected. Sometimes these vibrations are not water leaks, but are caused by other mechanical disturbances. It is quite common for the operator to pick up the conversation vibrations of a family living in the house supplied by the service which is being tested for leaks. A system of 100 miles of mains can be surveyed in about 18 days using radio equipment at a cost of about $3 per mile for labor only. Such a survey recently uncovered 242,000 gpd. of leakage. The value of this type of equipment is greatly reduced when working in highly congested business districts of our large cities.

Portable Meter Surveys

The pitometer rod or portable meter can be successfully used for locating leaks. This method requires the operation of almost all the valves in the system. A section of the city is valved off so that all of the water serving that area has to pass through one main. A pitometer rod is placed in this main and the volume of water passing the instrument is measured continuously, then each section of the main in the area is shut off, one at a time, so that the usage or leakage in that section can be measured by the pitometer. In this manner each section of main is tested for leaks. The pitometer rod is not necessary for this type of testing as a standard water meter placed around a valve by flexible hose connections can be substituted. A 2-in. meter is suitable for the larger size mains, and a ⅝-in. meter for the smaller size mains. The testing, of course, should be done when daily consumption is at the minimum. Pitometer surveys usually require the use of outside professional help.

TABLE 2

Analysis of Wastage Stopped in Cities of Various Sizes

Population Served	4,000	9,100	50,000	2,000,000	4,000,000	7,000,000
	per cent	*per cent*	*per cent*	*pre cent*	*per cent*	*per cent*
Live service leaks	93	75	34	18.0	51.0	42.5
Dead service leaks	3	21		23.0		3.5
Fire hydrant leaks	2	3			2.5	
Lead joint leaks	2	1		10.0	33.0	34.2
Main leaks			5	28.0	5.0	15.9
Miscellaneous leaks				1.5	7.0	
Slow meters			61	16.5		
Unauthorized use				3.0		
Inside plumbing						3.9
Valves					1.5	

Professional Leak Surveys

The employment of some national organization for conducting leak surveys is recommended. Although this

service may seem to be expensive, considering the reduction in pumpage and the increase in percentage of sales which such firms have accomplished, they may well be considered to pay for themselves.

Calculation Using Dye

Leaks can often be located in a main under pavement in a general area, but the exact location at which to break the pavement for making the repair is difficult to spot. All of the various types of sound equipment can be used to advantage in making the final location, assisted by the occasional driving of probe bars through the pavement near the water main. The Chicago water department has developed the dye method for spotting leaks after they have been located in a general area. This requires the shutting-off of all of the services on the line but gives the exact location of the leak. The dye method has been explained as follows (1):

After a section of main has been isolated and the service pipes shut off, when leakage is indicated, [an organic] dye (fuchsin) which colors the water red is passed into the pipe at the location of the by-passed valve.

This dye is contained in a tank under sufficient pressure so that it can be forced into the main under test. The rate in feet per second at which the dye-colored water in the main is moving can be determined by considering the cross-section of the main and the volume of water being recorded by the master meter. After this rate has been determined, the service pipe is disconnected at the first house meter and the water drawn off in a volume equal to the contents of the service pipe. If the dye has reached this point in the computed time, the water is shut off on the service pipe and the next service pipe opened and similarly tested. When a point is reached where the dye does not come through the service pipe in the time computed, it is necessary to draw off the uncolored water until the dye-colored water appears. The water thus drawn off is measured and, when the volume of the same is divided by the area of the cross-section of the pipe, the distance from the service pipe under test back to the point of the leak can be determined. In this way the location of an underground leak can be determined without the use of sound instruments or without excavating at random. This method has been used very successfully in the South Chicago district.

Better Meter Maintenance

The second part of this discussion deals with the unaccounted-for water that is permitted to slip through the meters without registration, and other phases of metering that are allied to this subject. The water department should be vitally interested in this subject because the water meters of the distribution system represent the cash registers of the water works business. Most of the water systems in this country either are completely metered or are in process of being metered. There is no assurance, however, that, because a water system is fully metered, all of the water used by the customers is being recorded on the meters. In fact, actual conditions would indicate that far too large a percentage is slipping through the meters. A water meter is like any other mechanism—it must be installed under the conditions for which it was designed to operated properly and then must be given the care and maintenance that would be given to any precision instrument.

Proper Size Selection

Many large water meters, 2 in. and more in size, have been installed on services which did not require them, just because the architect or building engineer showed too large a meter size on his drawing. The size, type and installation of large meters should be supervised by a water department employee qualified to know the requirements of the customer and the various rates of flow that will pass through the meters, so that the total quantity may be properly registered. It is often found that a 6-in. meter has been installed on a service of which the actual daily consumption would be far better recorded by a 2-in. meter.

The $\frac{5}{8}$-in. and $\frac{3}{4}$-in. meters customarily installed for house services should receive better maintenance than they ordinarily do. Many of these small meters are not tested from the time they are first installed until they have finally stopped due to failure of parts after 20 to 30 years of service. This is an expensive method of operation, as these meters are failing to register a large percentage of the water passed through them. All state commerce commissions regulating privately owned public water supplies require that the meters be tested at regular intervals, and there is no reason why municipally owned plants should not follow the same practice. The Illinois Commerce Com. specifies that a $\frac{5}{8}$-in. meter be tested every 10 years or after reading 100,000 cu.ft.; a $\frac{3}{4}$-in. meter, every 8 years or when reading 150,000 cu.ft.; and a 1-in. meter every 4 years. This is a liberal requirement; the increased revenue would justify a shorter period between tests.

Some cities allow large factories or other buildings to install fire protective systems without being metered or without providing any other means for the checking of unauthorized use from these lines by individuals throughout the plant. Meters should be installed for these systems to prevent this loss. Large losses have resulted from the failure of the water department to protect itself.

Survey of Meter Accuracy

The first meter that should be checked in starting a city-wide survey of unaccounted-for water is the totalizing meter located in the plant. These large meters have often been found in error due to the accumulation of lime or other chemicals used in treating the water. It is a simple procedure to check the plant meter by timing the drawdown in the clear well while the filters are shut off. The installation piping of plant meters should provide means for cleaning the throat, if of the Venturi type, and provide a by-pass for other types of meters, so that they may be periodically cleaned and overhauled.

The quality of $\frac{5}{8}$-in. meters has been greatly improved in recent years, especially the accuracy at low rates of flow. It is important that household meters accurately measure flows of about 0.25 gpm., for it has been shown that between 11 and 16 per cent of the water consumed is used at these low rates. If the meters register only a small percentage of such flows, or fail to register them altogether, the system will experience a large "unaccounted-for" loss and will also lose a good part of its legitimate revenue.

The number of small leaks throughout the household that will not register on old meters is surprising. One of the most common types of these leaks is found in the toilet flush box, which is often found to be wasting about one

pint per minute. A recent check on a vacant house with a toilet flush box leak and a new water meter showed a registration of 7,100 gal. over a 90-day period. Most of the old style meters with open gear trains will fail to register these small amounts. There are hundreds or thousands of these small leaks throughout the customers' premises that can be measured only by good meters, and all of this slippage is included in the unaccounted-for loss.

LaVerne Trentlage of Elgin, Ill., conducted a special test on 181 meters that had been in service 26 years. The over-all accuracy of these meters at a rate of flow of 0.25 gpm. was 11.9 per cent, and 78 per cent of the meters failed even to register. As the annual revenue lost from each of these meters, due to inaccuracy, averaged $3.47, the maintenance of household meters may be recognized as an important means of controlling unaccounted-for losses.

This waste of national resources can be reduced and brought within recognized standards of efficiency. Each year one hears of a few large cities that have conducted an intensive campaign against leaks and wastes. By hard work during 1929–1932, Pittsburgh saved 21.6 mgd. in waste. A second campaign in 1939 reduced the leaks by 8.3 mgd. Philadelphia recently saved 21.82 mgd. In a 15-year period, Chicago has found and stopped 239 mgd. of leakage. These are large cities and represent large savings, but the same proportion of national wealth can be saved in the smaller cities and towns all over the country.

Reference

1. Eddy, J. B. The Distribution System of the Chicago Water Works. Jour. A.W.W.A., **19**: 28 (1928).

Program for Routine Testing and Maintenance of Meters

By G. L. Williams

A paper presented on Oct. 25, 1946, at the California Section Meeting, San Francisco, Calif., by G. L. Williams, Analyst-Statistician, California Water Service Co., San Jose, Calif.

SOME kind of a program for the maintenance of water meters is dictated by good business management, which always requires careful consideration of each item of expenditure in the light of its contribution to the business as a whole. In the water business, which is caught between fixed rates for what it sells and rising costs of operation, and which faces unprecedented demands for service at a time when the construction dollar buys less and less, the necessity for such practical considerations is brought home very forcefully.

In initiating a program for the routine inspection and maintenance of water meters, the practical extent of the program and the proper interval for periodic maintenance must first be determined. The steps taken by the California Water Service Co. in developing such a program may be outlined herein, with the intent to obtain the answers to these questions and, at the same time, co-ordinate the routines necessary for the successful operation of the program and provide means for supervisory review of its effectiveness.

Planning the Program

As a first step, it was considered necessary to know the number of meters involved and their types and sizes, as well as the number of years they had been in service since the last test. Accordingly, these data were accumulated and then tabulated according to meter size and type and number of years in service. In considering the results, it was decided that certain sizes and types of meters, of special characteristics and limited number, would be treated as special cases, subject to replacement as opportunity afforded or to special consideration not covered by the general program.

With this information available, it was possible to:

1. Make an analysis of the costs of reconditioning.
2. Determine the average change in registration and consequent loss of revenue with years in service.
3. Determine the proper periodic interval for inspection, test and repair.
4. Develop methods for following up the results of the program.
5. Prepare a service manual by means of which all members of the organization could become fully acquainted with approved methods and practices for inspection, test and repair, as well as with the routines necessary for effective compliance with the program.

Cost of Reconditioning

Although the average cost of meter reconditioning was available from ex-

isting records, it was decided that the figures would be of little value, first, because they lumped together costs for all types and sizes of meters and were based on some questionable practices, and second, because such costs could not be used to establish standards of what constituted an efficient job.

A thorough review of the current methods and practices of testing and repairing meters was made, and provision was made for such changes as were considered necessary. After incorporation of these changes, a study was made of the cost of the material and the time required for each operation. From this study there was obtained an analysis of the cost of reconditioning, as shown in Table 1, detailing both the costs applicable to all meters (including removal, transportation and resetting) and the costs dependent upon the physical condition of each meter (such as the expenses involved in replacing pistons, measuring chambers and other parts). By applying these costs to the operations performed on meters of varying service ages, it became possible to compute the cost of reconditioning according to the length of time in service as well as by types and sizes.

Accuracy in Service

Where past records of tests are available, changes in the accuracy of registration with years in service can be ascertained:

1. By an analysis of the results of the tests of meters which had been removed from service for reasons other than non-registration, weighted against the average consumption at the rates of flow used for the tests.

2. By placing meters which have passed the required tests in series with meters of representative customers.

TABLE 1

*Costs of Removing, Testing, Repairing and Resetting ⅝-in. Meters**

Operation	Itemized Cost	Cost for 100 Meters
Removing and resetting		$ 45.00
Avg. transportation cost		6.00
Test before repair (labor)		6.30
Disassemble, examine, clean, reassemble		
Material	$ 9.70	
Labor	47.50	57.20
Test after repair		
Labor—9 minutes each		
Less—3 minutes each (on other work)		
Net—6 minutes each		9.50
Total Cost Applicable to All Meters		$124.00
Replace piston		
Material	$84.00	
Labor	7.00	$ 91.00
Replace intermediate gear train		
Material	185.50	
Labor	7.00	192.50
Replace measuring chamber		
Material	294.00	
Labor	7.00	301.00
Replace register (R.R.)†		
Material	122.50	
Labor	6.00	128.50
Replace register (S.R.)†		
Material	175.00	
Labor	6.00	181.00
Replace balls		
Material	21.00	
Labor	7.00	28.00
Miscellaneous		
Material	45.00	
Labor	9.00	54.00

* Figures are illustrative only.

† R.R.—round-reading; S.R.—straight-reading.

TABLE 2

*Comparison of Service and Test Meter Registration**

Acct. No.	Meter No.	Service Meter Reading		Water Registration by Service Meter	Test Meter Reading		Water Registration by Test Meter	Accuracy of Service Meter
		Start of Test	End of Test		Start of Test	End of Test		
		gal.	*gal.*	*gal.*	*gal.*	*gal.*	*gal.*	*per cent*
501	2042764	290	4,500	4,210	0	4,120	4,120	102
2816	2042771	76,040	81,790	5,750	90	7,740	7,650	75
919	2164599	50,060	55,260	5,200	0	5,350	5,350	97
3011	2164502	3,780	11,400	7,626	0	7,740	7,740	98
10922	2164148	15,070	21,870	6,800	0	6,750	6,750	101
15216	2423079	95,710	97,920	2,210	150	2,470	2,320	95
7900	2563997	86,570	93,220	6,650	0	7,590	7,590	88
11218	3646093	15,980	16,720	740	0	770	770	96
8615	5163846	18,350	20,410	2,060	0	2,010	2,010	102
14066	5251463	57,230	58,430	1,200	0	1,290	1,290	93
TOTALS				42,440			45,590	93

* Meters in service 11 years, in Stockton Dist.

Although many more meters can be used as a basis for the study by employing the first method than is practicable with the second, the former encounters the problem of converting differences in accuracy at test rates to a weighted average consumption at these rates. Practically, therefore, the same limitations are imposed as under the series test method. For this reason, as well as the fact that information available under past testing procedures was limited, the series test method was chosen as being more direct and probably more conclusive under existing conditions.

For the tests, 30 test meters were placed in series with the service meters of representative customers in districts which were chosen either because a cross-section of a large number of metered customers could be obtained or because special service conditions were encountered. In selecting representative customers, care was taken to include those which would give a fair sampling of the district's use of water. Also, because there was no evidence that changes in accuracy of registration would be evenly progressive with years in service, test meters were divided among those customers whose meters had been in service for 4, 7 and 11 years.

Readings of both test and service meters were taken at the time of installation and again after 30- and 60-day intervals. These data were arranged as shown in Table 2 in order to show differences in registration and in percentage of accuracy in comparison with the test meters for the three service years selected. The results are shown in graphic form in Fig. 1. It is notable that the average of all service meter registrations remains substantially in line with the test meters up to 7 years in service, after which there are enough meters with considerable under-registration to pull down the over-all average quite rapidly. Although the results were different in detail in each of the several districts from which data were collected, the characteristics of the curve were the same in all districts.

To forestall any questioning of the "100 per cent accuracy" assumed in the foregoing examples, it should be explained that, as all computations were made against the average accuracy of meters which had been calibrated within allowable percentages at each rate of flow, 100 per cent accuracy is assumed to be that of the average meter as placed in service. Also, it should be borne in mind that Fig. 1 indicates the average condition of service meters at given years of service; any individual meter may vary rather widely from this average.

Economic Maintenance Period

The time to recondition meters is when the cost of reconditioning is less than the cost of leaving the meter in service; in other words, when the annual cost of reconditioning is less than the annual loss of revenue. Reference to Fig. 1 shows that there is very little loss of registration accuracy for the first 7 years of service. After reconditioning, therefore, it can be expected that the average meter will follow the original performance curve, which, for these particular meters, means that their accuracy will be approximately equal to that of test meters up to 7 years of service, after which the same rapid decline in accuracy of registration will occur.

Conversion of registration losses into terms of losses in revenue is simple if only one rate applies. For the test, the number of step rates for varying consumption blocks and the practice of allowing a given volume of water for the minimum charge made it necessary to make an analysis of customer usage in order to determine the loss. A cross-sectional sampling of customer usage was made to determine the average number of customer months of consumption in each rate block, as well as the number of months under the minimum. This made it possible to determine the average loss in revenues for each drop of 1 per cent in meter registration. In Fig. 1, therefore, loss in revenues corresponding to loss in registration has been plotted against years in service.

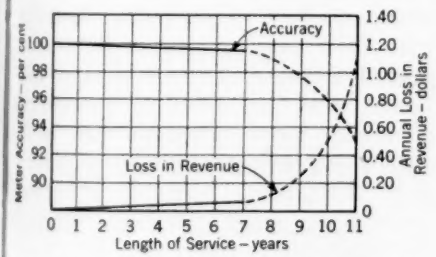

FIG. 1. Decline in Meter Accuracy and Revenues

By comparing the annual loss in revenue with the annual cost of reconditioning as previously obtained, the results might be:

Years of Service	Annual Loss In Revenue	Annual Cost of Reconditioning
7	$0.06	$0.33
8	0.32	0.33
9	0.90	0.29
10	1.56	0.26
11	2.65	0.24

These results show that meters should be reconditioned after nine years in service. In computing losses in registration, however, only two points were available, one at the 7-year and the other at the 11-year mark; and, because of special conditions, the computation assumes a straight line between these points, although a more usual performance would follow the curve shown in Fig. 1. As a further check, five test meters were shifted to other customers whose meters had been in service for the number of years indicated as the economic interval for reconditioning, readings being obtained after a 30-day interval. This is a fur-

ther refinement that may or may not be justified in all cases. In any event, under the conditions shown, the conclusions reached will not, for practical purposes, be greatly changed. The important conclusion reached from the study was that the period for reconditioning lies somewhere between 7 and 11 years of service.

Schedules and Reports

After establishment of the maintenance period, the information concerning the number of meters in service was utilized to lay out a schedule of the number of meters which should be removed from service for reconditioning over a given period. In order not to establish peaks in maintenance which would be beyond the capacity of facilities and personnel, this schedule was arranged to give as near an even annual load as was practicable, beginning with the older meters.

In actual practice, reference is made to a "meter history card," which shows the date of the last test, and an order for removal is sent to the field. The meter is removed from service, tagged with its identification and the reason for the test, and sent to the meter shop. Records of tests before and after repair, as well as code classifications indicating the reasons for and the extent of repairs, are made out in the meter shop for each meter received for routine test as well as for those received for other reasons. One copy of this test data sheet is used to record the pertinent data on the "meter history card"; the other copy is used to tabulate the number of meters reconditioned, showing cause of reconditioning and class of repair. Comparisons are made periodically of the number of meters reconditioned and the number scheduled for the period.

A standard or normal cost of reconditioning is obtained for each meter shop by applying the unit cost of reconditioning (obtained previously for purposes of the study) to the meters reported on the test sheets. The actual costs of reconditioning (as shown by the books) is compared periodically with this cost in order to detect any discrepancies which warrant further investigation and correction.

Meter Service Manual

A very important product of the program was the preparation of the *Water Meter Service Manual.* A complete description of this manual, which covers all phases of meter installation, replacement, testing and repair, as well as generally useful descriptive data and illustrations, is beyond the scope of this paper. Its general usefulness may best be shown by pointing out that the very act of setting down practices and procedures in complete detail served to bring out very forcibly those weaknesses which had crept in unnoticed.

General Application

Although the detailed methods used and the results obtained will be dictated largely by local service conditions, it is believed that the over-all approach to the problem described above is generally applicable. In these tests, 21 separate operating districts were involved, for which 5 meter test and repair shops are provided. The considerable number of operating districts, with their varying service conditions, tended to make the preliminary analytical work and checking procedures somewhat more elaborate than probably would be justified in all communities. As a result, however, it became possible to obtain otherwise unavailable comparative data.

Tentative

STANDARD SPECIFICATIONS

for

COLD WATER METERS—FIRE SERVICE TYPE

These "Tentative Standard Specifications for Cold Water Meters—Fire Service Type" are based upon the best known experience and are intended for use under normal conditions. They are not designed for unqualified use under all conditions and the advisability of use of the material herein specified for any installation must be subjected to review by the engineer responsible for the installation in the particular locality concerned.

American Water Works Association

Approved as Tentative by the Board of Directors of the A.W.W.A. on October 24, 1946

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Effective Date: These *"Tentative* Standard Specifications for Cold Water Meters—Fire Service Type" supersede, on January 1, 1948, the "Standard Specifications for Displacement, Current, Compound and Fire Service Meters" insofar as that document relates to fire service meters. The prior document was adopted by the A.W.W.A. May 24, 1923, and published in the *Manual of Water Works Practice,* p. 707 *et seq.*

Tentative

Standard Specifications for Cold Water Meters Fire Service Type

Section 4–1—General

Sec. 4–1.1—Scope

These specifications embrace the various types and classes of cold water compound meters (fire service type) for water works consumer service, and cover the materials and workmanship employed in their fabrication.

Sec. 4–1.2—Kind and Type

The kinds of meters covered are service meters of the compound type, which consist of the combination of a main meter of the proportional type for measuring large flows and a small displacement type meter for measuring small flows, in conjunction with an automatic valve mechanism. The combination is designed to afford a clear passage through the main meter when its valve is raised from the seat.

Section 4–2—Capacity and Size

Sec. 4–2.1—Capacity

Capacity or delivery classification shall be the quantity given in Table 1, Column 2, and is determined by the quantity delivered at the permissible maximum loss of head.

Meters shall have a loss of head not exceeding 4 psi. when the rate of flow is that given in Table 1, Column 2.

Sec. 4–2.2—Size

The size of the meter given in Table 1, Column 1, shall be in terms of the nominal size of opening in the inlet and outlet flanges of the meter.

Section 4–3—Design

Sec. 4–3.1—Cases

The outer cases shall be of bronze composition or of cast iron protected by a non-corrosive treatment. Castings shall not be repaired, plugged, brazed or "burned in."

All meters shall have cast on them, in raised characters, the size and model. The direction of the flow through the meter shall be properly indicated. Meters composed of a combination of independent units in separate housings shall have this information cast on each unit. Meters shall be designed for easy removal of all interior parts without disturbing the connections to the pipeline.

Sec. 4–3.2—External Bolts

All external bolts and washers shall be of non-ferrous material or protective treated iron or steel. Nuts shall be of non-ferrous material and shall be

TABLE 1
Fire Service Meters

(1) Meter Size, *in.*	(2) Safe Maximum Operating Capacity,* *gpm.*	(3) Maximum Loss of Head, *psi.*	(4) Minimum Test Flow, *gpm.*	(5) Normal Test Flow Limits, *gpm.*
3	400	4	2	8 to 400
4	700	4	2	8 to 700
6	1,600	4	4	16 to 1,600
8	2,800	4	7	28 to 2,800
10	4,400	4	12	48 to 4,400
12	6,400	4	12	48 to 6,400

* See Note 3a (re Excessive Wear).

designed for easy removal after having been long in service.

Sec. 4–3.3—Connections

Main case connections shall be flanged. Flanges shall be of the round type, faced and drilled, and shall conform to the American Standard cast-iron pipe flange, class 125, (ASA B16a—1939) for diameter, drilling and thickness. Companion flanges shall be faced and drilled, and they may be standard companion flanges, flange and bell, flange and spigot or combination of any. Standard companion flanges shall be tapped 3, 4, 6, 8, 10 and 12 in., respectively, American Standard internal taper pipe thread (ASA B2.1—1942).

Flange and bell, and flange and spigot connections shall be of cast iron and shall conform to the American Standard cast-iron pit-cast pipe, class 150, (ASA A21.2—1939) *as far as the specifications apply.* Companion flanges, gaskets, bolts, nuts and washers shall be provided.

Sec. 4–3.4—Registers

Registers may be either "round-" or "straight-" reading, indicating in cubic feet or gallons.

3.4.1—*Round-Reading Registers*

The register pinion and spur gears shall be firmly fastened on their spindles, shall fully mesh with each other and run freely and shall be so constructed that they cannot become unmeshed. The spindle bearings in the top and bottom register plates shall be bushed with hard vulcanized rubber or other non-metallic bushings. These bushings shall have sufficient depth to insure ample spindle bearing and sufficient clearance to allow the spindles to revolve freely; shall be fitted so they will not work loose; shall be removable; and shall be as nearly as possible non-warping, non-shrinking and non-expanding in heat. The register throughout, except for the dial and index hands, shall be plated or given other protective treatment, or shall be made of material as nearly non-corrosive as possible.

The maximum indication of the initial dial and the minimum capacity of the register of the main unit, when indicating cubic feet, shall be as given in Table 2, Columns 2 and 4, and, when indicating gallons, as given in Columns 3 and 5. The maximum indication of the initial dial and the minimum capacity of the register of the by-pass

TABLE 2

Fire Service Meters—Main Unit

(1) Meter Size, *in.*	Maximum Indication of Initial Dial		Minimum Capacity of Register	
	(2) *cu.ft.*	(3) *gal.*	(4) *mil.cu.ft.*	(5) *mil.gal.*
3	100	1,000	10	100
4	100	1,000	10	100
6	100	1,000	100	1,000
8	1,000	10,000	100	1,000
10	1,000	10,000	100	1,000
12	1,000	10,000	1,000	10,000

unit, when indicating cubic feet, shall be as given in Table 3, Columns 2 and 4, and, when indicating gallons, as given in Columns 3 and 5.

All the index circles, including the initial circle, shall be subdivided into ten equal parts. All hands or pointers shall taper to a sharp point and shall be accurately set and securely held in place.

3.4.2—*Straight-Reading Registers*

The figures on the number wheels shall be large and distinct so that they can be read easily. The register lock and side gears shall be securely fastened to their number wheel discs and hubs. The tumbler pinions shall mesh accurately at the turnover points with the lock and side gears of the adjacent number wheels. Both main and pinion shafts shall be so secured in the register frame that they cannot get out of position. The pinion shaft shall be so designed that there is no possibility of its bending and allowing the pinion to skip at the turnover point. All parts of the register shall be plated or given a protective treatment, or shall be made of material as nearly non-corrosive as possible.

The maximum indication of the digits appearing on the first number wheel and the minimum capacity of the register of the main unit, when indicating cubic feet, shall be as given in Table 2, Columns 2 and 4, and, when indicating gallons, as given in Columns 3 and 5. The maximum indication of the digits appearing on the first number wheel and the minimum capacity of the register of the by-pass unit, when indicating cubic feet, shall be as given in Table 3, Columns 2 and 4, and, when indicating gallons, as given in Columns 3 and 5.

There shall be a test index circle which shall be divided into ten equal parts. The hand or pointer shall taper to a sharp point and shall be accurately set and securely held in place.

Sec. 4–3.5—Register Boxes

Register boxes and lids shall be made of bronze composition or shall be of the same material as the top case, with the name of the manufacturer cast on the lid in raised letters. The serial number of the meter shall be plainly stamped on the lids of both the main and by-pass units. If required, the serial number shall also be stamped on

TABLE 3

Fire Service Meters—By-pass Unit

(1) Meter Size, *in.*	Maximum Indication of Initial Dial		Minimum Capacity of Register	
	(2) *cu.ft.*	(3) *gal.*	(4) *mil.cu.ft.*	(5) *mil.gal.*
1½	10	100	1	10
2	10	100	10	100
3	10	100	10	100
4	100	1,000	100	1,000
6	100	1,000	100	1,000

the cases. The lids shall be recessed and shall lap over the box so that dirt will be prevented from accumulating on the glass. The glass shall be inserted from the inside and shall be securely held in place without the use of putty or pins. All register compartments shall be provided with a water escape hole $\frac{1}{8}$ in. in diameter. Register box screws shall be drilled for seal wire holes not less than $\frac{3}{32}$ in. in diameter. When the meter is equipped with hoods, the register box lids may be omitted.

Sec. 4–3.6—Intermediate Gear Trains

Intermediate gear trains may be mounted on the measuring chambers or in the upper main casings. Gear train frames, spindles, gears and pinions shall be made of durable non-ferrous material. Pinions and spur gears shall be firmly fastened, shall fully mesh with each other and shall run freely. The lower end-bearings for pinion and spur gear spindles that revolve shall be fitted with hard vulcanized rubber or other non-metallic bushings fastened in place so that they will not fall or work out and shall be easily removable. Gear trains may be of either the oil-enclosed or open type. If of the oil-enclosed type, the gear trains shall have a separate housing or shall form a housing with the main casings or measuring chamber and shall operate in a suitable lubricant.

Sec. 4–3.7—Measuring Chambers

3.7.1—*Displacement*

The measuring chambers for displacement type meters shall be made of bronze or non-ferrous composition and shall not be cast as part of the outer casings. They shall be machined carefully and secured in position in the outer casings so that any slight distortion of the casings which might occur under 150-psi. pressure will not affect the sensitiveness of the meters.

3.7.2—*Proportional*

The measuring chambers or cages for proportional type meters shall be made of bronze or non-ferrous composition and shall be self-contained units, firmly seated and easily detached and removed from the main case. Chambers with impellers that have revolving spindles shall have long, hard-rubber-bushed removable bearings for such spindles. Chambers with impellers that revolve around a stationary

stem shall contain a rigid, centrally located, stationary stem for suspending the impeller.

Sec. 4–3.8—Pistons

The measuring pistons of the displacement type meters shall be made of vulcanized hard rubber, shall be smoothly machined, shall be fitted accurately in their measuring chambers and shall operate smoothly and freely. The plates of disc pistons, whether flat or conical, shall have metal reinforcements or shall be equipped with thrust rollers. Disc pistons may be in one piece or the piston plates may be in one piece and the piston balls in two pieces. The piston spindles or shafts shall be securely fastened in the pistons.

Sec. 4–3.9—Impellers

Measuring impellers, wheels or pistons of the proportional type meters shall be made of vulcanized hard rubber. The measuring impeller shall be mounted, or shall rotate on phosphor-bronze or other suitable metal spindle and shall be supported by jewel, ball or other suitable bearings. Measuring impellers mounted on spindles shall revolve in hard-rubber-bushed bearings. The measuring impeller, together with its spindle, shall be as nearly as possible of the same specific gravity as water.

Sec. 4–3.10—Main Controlling Valves

The controlling valve shall be of the mechanical or atmospheric type, in which the initial resistance to opening, for all practical purposes, vanishes after opening. The valve shall cut off all flow through it when the main meter is not in operation, shall effectively prevent backflow and shall not bind or stick in service.

3.10.1—*Mechanical Valves*

The mechanical valve may be of the compound swing or lever type, or of any mechanical type suitable. It shall close by gravity, and the weight of the valve and any supplemental weight imposed on it shall offer sufficient resistance to the incoming water to divert all small rates of flow through the by-pass meter and shall open under a difference of pressure not exceeding 4 psi. When the amount of water being used through the by-pass meter results in a loss in pressure of 4 psi. between inlet and outlet sides of the main meter, the valve shall open and the water passing through the valve shall be recorded on the main meter; and, when the valve is unseated, there shall be a clear passage through the meter. The valve weights shall be of bronze or lead, or of a bronze shell loaded with lead. The valve and supplemental weight pins or spindles shall be of bronze or other suitable non-ferrous material, and all valve and supplemental weight hinge bearings shall be bushed with bronze or hard rubber. If the valve contains a clapper, it shall be faced with semi-hard rubber. Valve seats shall be of bronze, shall have the narrowest satisfactory width of face, shall be screwed into position and shall be equipped with sturdy lugs for easy removal.

3.10.2—*Atmospheric Valves*

The atmospheric valve shall be of the swing type, with an opening between the valve seat and atmosphere so designed that the initial resistance to opening shall not exceed 6 per cent of the pressure on the inlet side. The difference in pressure caused by the atmospheric opening and any supplementary weight imposed on the valve shall hold the valve closed and divert

small rates of flow through the by-pass meter. When the amount of water used exceeds a rate which would result in a pressure loss equal to 6 per cent of the inlet pressure, the valve shall open, and the water passing through the valve shall be recorded on the main meter. The valve shall contain a semi-hard rubber gasket for seating purposes.

Sec. 4–3.11—By-pass Check Valve

All meters shall be provided with check valves on the by-passes. The check valve interior mechanism shall be of bronze or other suitable non-ferrous material. They shall effectively prevent backflow and shall not bind or stick in service.

Section 4–4—Registration

The registration on the meter dials shall indicate the quantity recorded to be not less than 97 per cent nor more than 103 per cent of the water actually passed through the meter while it is being tested at any rate of flow within the limits specified in Table 1, Column 5, under "Normal Test Flow Limits," except in the registration of flows within the "change-over" from by-pass meter to main meter. The registration at these rates of flow shall not be less than 85 per cent. The difference in the rate of flow at the beginning and at the end of the "change-over" shall not exceed the figures in the following table:

Meter Size, *in.*	Rate of Flow, *gpm.*
3	40
4	60
6	130
8	210
10	300
12	400

The beginning of the "change-over" is when the accuracy of registration falls below 97 per cent, due to the operation of the automatic valve mechanism, and the end of the "change-over" is when the accuracy of registration again reaches 97 per cent.

Not less than 95 per cent of actual flow shall be recorded when a test is made at the rate of flow set forth in Table 1, Column 4, under "Minimum Test Flow."

Section 4–5—Pressure Test

Meters shall be guaranteed to operate under a working pressure of 150 psi. without leakage or damage to any part. The check valves on main and by-pass meters shall be able to resist a back-pressure of 150 psi.

Section 4–6—Workmanship and Materials

Meters shall be guaranteed against defects in materials and workmanship for a period of one year from date of shipment. Parts to replace those in which a defect has developed within such period shall be supplied without charge, piece for piece, upon the return of such defective parts to the manufacturer thereof or upon proper proof of such defect.

Section 4–7—Rejected Meters

The manufacturer shall, at his own expense, replace or satisfactorily readjust all meters rejected for failure to comply with these specifications.

NOTES

These notes are not part of the specifications. They are given only as information concerning the testing and care of meters and important materials used in meter construction. They are not intended to limit in any way the future development of better materials for general use or the use of special metals with specific waters which may require materials of different composition to give service equal to that recorded in normal practice.

(1) *Tests*

Capacity tests are those which test the design of the meter. When a meter of a given design has once been tested for capacity, it should not be necessary to test this type of meter again unless a change has been made in the design.

Registration tests are those which test the assembly and workmanship of the meter. Each meter should be tested for registration, as there is no certainty that, because one meter of a given design is within certain limits of accuracy, all meters of this design will necessarily give similar results. The register furnished with each meter should be used by both the manufacturer and the purchaser in making registration tests.

All meters should be tested for accuracy of registration within, and as near as practicable to, the low and high rates given under "Normal Test Flow Limits," and occasionally additional tests should be made at one or more intermediate points. A test at the "Minimum Test Flow" should be made on all meters.

A pressure test should be made on each size of meter of a particular design furnished. This pressure is to be 150 psi. and may be obtained by the use of a hand pump or any method available. The meter should be tested for accuracy before and after it has been tested by static pressure to determine whether there has been any distortion that would affect the registration. It is unnecessary to make more than one pressure test on each size of a given design if satisfactory results are obtained. A working pressure test is preferable to a static pressure test.

If the purchaser has no testing equipment, a certificate should be furnished by the manufacturer showing that each meter has been tested for accuracy of registration, that it complies with the specifications and that the size and design comply with the capacity requirements.

(2) *Testing Equipment*

The minimum test equipment is as follows:

(a) A valve on the supply line which would permit the starting and stopping of the flow without appreciable loss of time.

(b) A valve or other suitable device on the discharge line which can provide the rate of flow desired.

(c) Pressure gages on supply and discharge pipes, so that any change in pressure which would affect the rate of flow can be detected. The discharge pipe must be under sufficient head to guarantee a pressure on the outlet of the meter.

(d) A measuring device of either the volumetric or weighing type. The accuracy of the determination of the amount of water discharged should be such as to bring the limit of error within 0.25 per cent. The amount of water passed should be sufficient to cause at least one revolution of the pointer on the initial dial except for the test at the "Minimum Test Flow" rate. The amount passed at the "Minimum Test Flow" rate should be of sufficient quantity to secure a true indication of the accuracy.

(e) Two piezometer rings of exactly the same diameter for capacity tests. The piezometer rings must be free from any burrs where the holes are drilled through the wall of the ring, and not fewer than four holes shall be provided, drilled in pairs on diameters at right angles to each other. The inlet ring shall be set close to the meter at a distance of eight diameters or more below the nearest upstream stop valve or fitting, and the outlet ring shall be placed at a distance of between eight and ten diameters from the outlet of the meter. The diameter of the rings, the inlet and the outlet pipes shall be the same as the size of the meter to be tested. The rings are to be connected to a mercury U-tube, equipped with an accurate adjustable scale for measuring the difference in mercury level, by rubber or metallic tubing. Provision is to be made for the complete removal of air from the U-tube and the tubing connected therewith, and the installation is to be such that air will rise to the air outlets. Where relatively high flows are to be measured, it is necessary to read both sides of the mercury column simul-

taneously in order to compensate for irregularities in the diameter of the glass U-tube and to avoid errors due to fluctuations.

Suitable pressure gages may also be used.

(3) *Care of Meters*

In a fire service meter the motions of the pistons and impellers are transmitted by a system of gearing to the register where the flow is recorded in convenient units of measure, as cubic feet or gallons. The gearing serves to translate the motion of the pistons and impellers into the unit of measure indicated by the registers. The register is at all times a measure of the number of revolutions of the pistons or measuring impellers in terms of cubic feet or gallons. It records a true measure of flow only when the meter has been properly calibrated by gear adjustment, and after proper calibration will continue to register correctly only as long as the piston and impeller continue to make the proper number of cycles for each unit of quantity passed through the meter. If, after calibration, any condition should develop, whereby the pistons or impellers are compelled to make less than the proper number of cycles per unit of quantity passed through it, the meter will under-register. If the pistons or impellers are compelled to make more than the proper number of cycles, the meter will over-register. The proper number of cycles is the number made at the time the meter is calibrated. The measurement of flow recorded on the main unit, through which only a relatively small portion of the total flow actually passes, is likely to be inaccurate unless careful attention is given to keep all parts of the meter in the best working condition. Under ordinary working conditions, there are a number of factors that may cause under- or over-registration after comparatively short intervals. The more important of these factors which should be guarded against to secure proper registration are:

(a) *Excessive Wear.* Excessive wear of the moving parts of the meter may be caused by improper setting, by over-speeding or, in general, by the selection of a meter too small for the work required. The effect of excessive wear of the pistons, impellers or measuring chambers is slippage and under-registration. Excessive wear of the intermediate gear trains may cause binding of the gears or gear slippage. In any case, if the meter is not stopped entirely, under-registration will result. To avoid excessive wear, meters should be set in a horizontal position and should not be run at destructive speeds. The capacity of the meters given in the specifications represents the maximum rates of flow at which water should be passed through the meters for short periods of time or the peak loads which should come upon meters only at long intervals.

(b) *Temperatures.* High temperatures cause expansion of the rubber pistons and impellers, which tends to create unusual friction or to bind the piston or impeller in its chamber. The effect is slippage and under-registration or failure of the meter. Low temperatures have no noticeable effect on the working parts of the meter. Freezing will stop the meter and possibly damage it.

Cold water meters are not affected by temperatures up to about 80°F. In warm climates, where the temperature of the water is likely to go above 80°F., meters with clearances slightly larger than ordinary should be used, and accuracies indicated in the specifications must be modified accordingly.

To avoid troubles caused by temperature, meters should be set at locations where they will be protected from heat and frost. At locations where the hot water from heating systems may be forced back through the meter, a check valve and temperature and pressure relief valve should be installed on the outlet side of the meter.

(d) *Corrosion.* All the metals used in the construction of a meter are affected by the corrosive action of water. The action is very slow with most potable waters. The result is that parts of the meter are weakened, particularly the teeth of the open intermediate gears, and, with meters that are idle for long intervals, there is a tendency toward binding. Tuberculation of the outer case in meters of the proportional type may change the normal direction of flow and cause inaccurate registration.

(d) *Material in Suspension.* Foreign material carried in suspension has a tendency to fill the space between the piston and measuring chamber and cause over-registration of displacement meters. Such over-registration, however, is limited and cannot generally exceed 3 per cent.

Accumulations of deposit always tend to cause inaccurrate registration of proportional

meters, as any conditions tending to change the velocity of flow, after the meter has been calibrated, will cause inaccurate registration. Such inaccurate registration is not limited.

Sand is especially destructive, and care should be exercised to prevent sand from reaching the pipes supplying the meters.

The finer particles of suspended material cannot be prevented from reaching the meter, and troubles from this source can be avoided only by cleaning the meter periodically, the interval between cleanings depending upon the quality of the water.

(e) *Periodic Tests.* Meters properly selected as to size and type will give satisfactory service over a long period of time without attention only when operated under ideal conditions. Under ordinary conditions, meters must be given some care if they are to function properly. In most cases it is impossible to ascertain, without actual test, whether a meter which has been in service is registering within the required degree of accuracy. Consequently, to insure reliable meter measurements, it is essential that all meters be subjected to periodic tests. The interval between tests and the method of conducting them must be governed largely by local conditions. Under *average* conditions the following intervals between tests should not be exceeded:

Meter Size *in.*	Years Between Tests
3	3
4	2
6	1
8	1
10	1
12	1

Many state regulatory commissions specify the intervals between tests on both a time and quantity basis.

Meters of the fire service type used for measuring unfiltered surface waters should be cleaned about once a year in order that they may be kept in good working condition. When filtered or exceptionally clean water is used, the intervals between cleanings may be longer.

Best results will be obtained from fire service meters if they are calibrated in place, since the accuracy of these meters is affected by changes in distribution of velocities through the meter. A meter of this type, calibrated in a testing machine under conditions where there is a bend near the inlet side of the meter, may register incorrectly from the start if installed under conditions where there is a straight run of pipe in the inlet side. Any other condition tending to change the distribution of velocities as existent at the time of calibration will have the same effect. If calibrated on the premises this source of error is minimized.

(4) *Bronze*

A bronze which is satisfactory for most waters is that of specifications B62–36 of the American Society for Testing Materials or No. 2 Federal Specifications QQ–B–691a for an alloy of copper, tin, lead and zinc, known commercially as composition metal, 85–5–5–5, ounce metal, red brass or hydraulic bronze.

(5) *Rubber*

A satisfactory rubber for pistons, measuring impellers and bushings should, among other items, have a specific gravity under 1.2, a minimum tensile strength of 6,500 psi., a maximum elongation of 5 per cent, a hardness (scleroscope test) of not less than 67, a free sulfur content of 3 per cent or less, a free ash content of not more than 3 per cent and a uniformity of cure and physical characteristics.

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **34:** 412 (Mar. '42) indicates volume 34, page 412, issue dated March 1942. If the publication is paged by the issue, **34:** 3: 56 (Mar. '42) indicates volume 34, number 3, page 56, issue dated March 1942. Initials following an abstract indicate reproduction, by permission, from periodicals, as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M.—Institute of Metals (British).*

HEALTH AND HYGIENE

Typhoid in the Large Cities of the United States in 1945. ANON. J. Am. Med. Assn., **131**: 817 (1946). Previous annual summaries reproduced in Journal as follows: **20**: 257; **21**: 963; **22**: 1122; **23**: 1059; **24**: 1066; **25**: 1157; **26**: 939; **27**: 1593; **28**: 1123; **29**: 1177; **30**: 1456; **31**: 1561; **32**: 1394; and **34**: 449. Last review of typhoid deaths was for '42. Two succeeding years omitted, but statistical data for '43 and '44 included in present summary. As in previous years, communication was addressed to the health officer of each of the cities requesting number of deaths from typhoid, excluding paratyphoid, both among residents and nonresidents as recorded in each of the 3 years '43–'45. Each health officer asked to record estimate of pop. for each of the 3 years. Some continuing to use '40 census figures; others prepared local estimates, using ration book data or adjustments which are questionable. For most cities of 100,000 pop. or more, Census Bureau has no estimates of pop. for dates since'40. Figures exist for some, based on special censuses or sample censuses for various dates since '40. Figures available for the total pop. of cities (Detroit, Long Beach, Los Angeles, Norfolk, Oakland, Portland, San Diego, San Francisco, Seattle, Tacoma) in 10 congested production areas, where sample censuses taken by Census Bureau in '44. Special census also taken in San Francisco in Aug. '45. Estimates of the civilian pop. of counties available for Mar. 1 and Nov. 1, '43, based on registrations for war ration books 2 and 4. Some cities (Baltimore, Denver, New Orleans, New York, Norfolk, Philadelphia, Richmond, St. Louis, San Francisco, Washington) coterminous with counties, and the figures given in the releases are city as well as county estimates. Estimates of total pop. of Washington made for July 1 of each year 1940–44. Since for vast majority of cities no official figures available for any date subsequent to that of the '40 federal census, again been deemed advisable to employ the pops. detd. by this uniform tabulation. Recognized that, in areas of concentration of military and industrial activities, slight error will result, and some city and group rates may be a little too high and even too low. For cities for which special census figures are available, corrections in rates shown in footnotes to tables. In most, there are no changes in rates. No rate extended beyond first decimal point, and this creates slight disadvantage for very large cities which now have but a single death from typhoid (Chicago, Detroit). Paratyphoid again excluded. Special note made of cities in which all deaths occur among nonresidents. In addition to the 58 cities enumerated on the honor roll in Table 1, 8 cities (Columbus, Detroit, Indianapolis, Knoxville, Nashville, New Orleans, San Francisco, Wilmington) qualified for such acclaim but charged with typhoid deaths among nonresidents cared for in these cities. [Advice from Omaha indicates that reported 0.4 death rate is result of error in tabulation, and that this city had no deaths in '45. To this extent, therefore, tables are inaccurate.] In 8 other cities (Atlanta, Baltimore, Birmingham, Camden, Cincinnati, Houston, Louisville, Richmond) more than ½ of reported deaths stated to have been among nonresidents. One city with more than one million inhabitants (Detroit) records no death among residents. Number of cities with no typhoid death during past 2 or more years increased from 31 in '42 to 41 in '45 (Table 2). Fort Wayne continues to head

TABLE 1

Typhoid Death Rates in 1945

Honor Roll: No Typhoid Deaths (58 Cities)‡

Akron	Evansville	Minneapolis	South Bend
Albany	Fall River	New Haven	Spokane
Bridgeport	Flint	Oakland	Springfield
Buffalo	Fort Wayne	Oklahoma City	Syracuse
Canton	Gary	Paterson	Tacoma
Cambridge	Grand Rapids	Peoria	Toledo
Charlotte	Hartford	Portland	Trenton
Chattanooga	Jersey City	Providence	Tulsa
Cleveland	Kansas City, Kan.	Reading	Utica
Denver	Kansas City, Mo.	Rochester	Waterbury
Des Moines	Long Beach	Salt Lake City	Wichita
Duluth	Lowell	San Diego	Worcester
Elizabeth	Lynn	Scranton	Yonkers
El Paso	Memphis	Somerville	Youngstown
Erie	Milwaukee		

First Rank: From 0.1 to 1.9 Deaths per 100,000 (37 Cities)§

Boston 0.1	Los Angeles 0.3	Newark 0.5	Knoxville 0.9*
Chicago 0.1	Seattle 0.3	Fort Worth 0.6	New Bedford 0.9
Detroit 0.1*	St. Paul 0.3	Jacksonville 0.6	Sacramento 0.9
New York 0.1	Washington 0.3	Louisville ..... 0.6†	Wilmington 0.9*
St. Louis 0.1	Cincinnati ..... 0.4†	Miami 0.6	Atlanta ..... 1.0†
Baltimore ..... 0.2†	Omaha 0.4	Nashville 0.6*	New Orleans 1.2*
San Francisco 0.2*	Pittsburgh 0.4	Philadelphia 0.6	Camden ..... 1.7†
Columbus 0.3*	San Antonio 0.4	Norfolk 0.7	Tampa 1.8
Dallas 0.3	Dayton 0.5	Houston ..... 0.8†	Birmingham ..... 1.9†
Indianapolis 0.3*			

Second Rank: From 2.0 to 2.1 (1 City)

Richmond ..... 2.1†

* All typhoid deaths were stated to be in nonresidents.
† One third or more of the reported typhoid deaths were stated to be in nonresidents.
‡ Fifty-six without Charlotte and Gary.
§ Thirty-six without Sacramento.

TABLE 2

*Cities With No Typhoid Deaths in 1944–45 (41 Cities *)*

City	Years†	City	Years†
Albany	5	Minneapolis	4
Bridgeport	4	New Haven	2
Canton	6	Oakland	2
Cambridge	8	Paterson	4
Chattanooga	4	Peoria	2
Denver	2	Reading	4
Des Moines	6	Salt Lake City	4
Duluth	7	San Diego	3
Erie	6	Scranton	6
Evansville	5	Somerville	5
Fall River	9	Springfield	7
Fort Wayne	11	Toledo	2
Gary	5	Trenton	5
Grand Rapids	6	Tulsa	6
Hartford	7	Utica	3
Jersey	3	Waterbury	2
Kansas City, Kan.	2	Wichita	3
Long Beach	2	Worcester	4
Lowell	2	Yonkers	7
Lynn	9	Youngstown	4
Milwaukee	2		

* Forty without Gary.
† Number of years with no typhoid deaths.

list with no death in 11 years. South Bend, with excellent record of no death for 8 years, recorded 1 among nonresidents in '44, but none among residents for 10 years. Fall River and Lynn report no death in 9 years, Cambridge none in 8 years. *New England cities* (Table 3) (pop. 2,579,152), which usually reported lowest group rate, trailed East North Central cities (0.07) by narrow margin (0.08). Lowest group rate thus far attained (0.04) recorded by New England cities in '44 with but 1 death from typhoid. In '45 but 2 deaths, one each in Boston and in New Bedford. This marks first death in latter city for 9 years. West North Central cities (0.11) not far behind in group rate. 12 New England cities (there were 11 in '42, 10 in '43, 13 in '44) report no death from typhoid in '45 (Table 1). 6 cities (Cambridge, Fall River, Hartford, Lynn, Somerville, Springfield) record no death during quinquennium '41–45. Hartford and Springfield report no death for 7 years. While in '40 ½ of the 18 cities recording no deaths from typhoid during 2-year period

TABLE 3

Typhoid Death Rates per 100,000 Population of 96 Large Cities, by Geographic Divisions, 1906–45

City	1945	1941–1945	1936–1940	1931–1935	1926–1930	1921–1925	1916–1920	1911–1915	1906–1910
New England States									
Cambridge	0.0	0.0	0.2*	0.8	2.1	4.3	2.5	4.0	9.8
Fall River	0.0	0.0	0.2	0.2	2.2	2.3	8.5	13.4	13.5
Lynn	0.0	0.0	0.2	0.2	1.5	1.6	3.9	7.2	14.1
Springfield	0.0	0.0	0.3*	1.1†	0.4	2.0	4.4	17.6	19.9
Hartford	0.0	0.0	0.5	1.0†	1.3	2.5	6.0	15.0	19.0
Somerville	0.0	0.0	0.6	0.4	1.3	1.6	2.8	7.9	12.1
Worcester	0.0	0.1	0.2*	0.5*	1.0	2.3	3.5	5.0	11.8
Bridgeport	0.0	0.1	0.4	0.3	0.5	2.2	4.8	5.0	10.3
Lowell	0.0	0.2	0.4	1.2	2.6	2.4	5.2	10.2	13.9
Providence	0.0	0.2†	0.6	1.1†	1.3	1.8	3.8	8.7	21.5
New Haven	0.0	0.2†	1.0	0.7†	0.6	4.4	6.8	18.2	30.8
Waterbury	0.0	0.8	0.2	0.4	1.2	1.0	8.0	18.8	....
Boston	0.1	0.1	0.3†	0.6	1.2	2.2	2.5	9.0	16.0
New Bedford	0.9	0.2	0.4	1.1	1.5	1.7	6.0	15.0	16.1
Middle Atlantic States									
Yonkers	0.0	0.0	0.3	0.7	0.5	1.7	4.8	5.0	10.3
Scranton	0.0	0.0	0.3	1.4	1.8	2.4	3.8	9.3	31.5
Erie	0.0	0.0	0.7†	1.2	0.9	2.3	6.9	49.0	46.6
Albany	0.0	0.0	1.2†	1.2	1.8	5.6	8.0	18.6	17.4
Trenton	0.0	0.0	1.4†	1.1	2.1	8.2	8.6	22.3	28.1
Rochester	0.0	0.1	0.3†	0.4	1.7	2.1	2.9	9.6	12.8
Jersey City	0.0	0.1†	0.6	0.3	0.9	2.7	4.5	7.2	12.6
Paterson	0.0	0.1*	0.7†	0.9	1.0	3.3	4.1	9.1	19.3
Buffalo	0.0	0.2	0.1	0.6	2.7	3.9	8.1	15.4	22.8
Reading	0.0	0.2	0.5	0.4	1.6	6.0	10.0	31.9	42.0
Syracuse	0.0	0.3†	0.3*	0.8	0.8	2.3	7.7	12.3	15.6
Utica	0.0	0.4†	0.2*	0.2	1.1	3.9‡	....	....	....
Elizabeth	0.0	0.4	0.5	0.9	1.6	2.4	3.3	8.0	16.6
New York	0.1	0.1	0.3	0.8	1.3	2.6	3.2	8.0	13.5
Pittsburgh	0.4	0.3	0.7	0.9	2.4	3.9	7.7	15.9	65.0
Newark	0.5	0.1	0.3	0.4	0.9	2.3	3.3	6.8	14.6
Philadelphia	0.6	0.3	0.8	0.9	1.1	2.2	4.9	11.2	41.7
Camden	1.7†	0.5†	1.4†	2.7	4.4	5.9	4.9	4.5	4.0
South Atlantic States									
Charlotte	0.0	0.6†	1.6†	2.5	....	....	....	....	....
Baltimore	0.2†	0.3†	0.9†	1.4	3.2	4.0	11.8	23.7	35.1
Washington	0.3§	0.4†§	1.1	2.2	2.8	5.4	9.5	17.2	36.7
Miami	0.6	0.6	2.4	2.0	3.5	....	....	....	....
Jacksonville	0.6	0.8	2.3	1.6	4.4	....	....	....	....
Norfolk	0.7§	0.3§	1.1†	3.3	2.2	2.8	8.8	21.7	42.1
Wilmington	0.9*	0.2*	0.5	1.5	3.1	4.7	25.8‡	23.2‡	33.0
Atlanta	1.0†	0.5†	2.1†	7.3	11.1	14.5	14.2	31.4	58.4
Tampa	1.8	1.8	0.6†	3.4	3.8	19.1	43.9‡	....	....
Richmond	2.1†‖	1.3†‖	2.5†	2.4	1.9	5.7	9.7	15.7	34.0
East North Central States									
Fort Wayne	0.0	0.0	0.0	2.1	4.2	12.9	7.3	....	....
Canton	0.0	0.0	0.4†	0.8	1.4	3.3	8.9	....	....
Grand Rapids	0.0	0.0	0.5†	0.2	1.0	1.9	9.1	25.5	29.7
Gary	0.0	0.0	1.1	0.8	....	....	....	....	....
Evansville	0.0	0.0	1.2†	1.8	6.2	5.0	17.5	32.0	35.0
Milwaukee	0.0	0.1	0.1	0.2	0.8	1.6	6.5	13.6	27.0
Akron	0.0	0.1*	0.6†	0.9	1.5	2.4	10.6	21.0	27.7‡
Youngstown	0.0	0.1*	0.7	1.2	1.1	7.2	19.2	29.5	35.1
South Bend	0.0	0.2*	0.0	0.8	....	....	....	....	....
Cleveland	0.0	0.2	0.6	1.1	1.0	2.0	4.0	10.0	15.7
Flint	0.0	0.2	1.3†	0.8	1.6	4.6	22.7	18.8	46.9
Peoria	0.0	0.6†	1.3†	0.9	0.2	3.7	5.7	16.4	15.7‡
Toledo	0.0	1.1	1.0†	1.2	3.0	5.8	10.6	31.4	37.5
Chicago	0.1	0.1	0.3	0.4	0.6	1.4	2.4	8.2	15.8
Detroit	0.1*	0.1	0.4	0.7	1.3	4.1	8.1	15.4	22.8
Indianapolis	0.3*	0.3†	1.2†	1.8	2.7	4.6	10.3	20.5	30.4
Columbus	0.3*	0.4†	1.4†	1.9	2.1	3.5	7.1	15.8	40.0
Cincinnati	0.4†	0.3†	1.1†	1.4	2.5	3.2	3.4	7.8	30.1
Dayton	0.5	0.3†	1.4	0.8	1.9	3.3	9.3	14.8	22.5

TABLE 3—*Continued*

City	1945	1941–1945	1936–1940	1931–1935	1926–1930	1921–1925	1916–1920	1911–1915	1906–1910
East South Central States									
Chattanooga	0.0	0.2	0.9	5.8	8.0	18.6	27.2	35.8‡	....
Memphis	0.0	0.3†	4.0†	7.5	9.3	18.9	27.7	42.5	35.3
Louisville	0.6†	0.5†	0.9	2.8	3.7	4.9	9.7	19.7	52.7
Nashville	0.6*	0.5*	3.4†	5.7	18.2	17.8	20.7	40.2	61.2
Knoxville	0.9*	1.2*	3.8	6.0	10.7	20.8	25.3‡	....	....
Birmingham	1.9†	0.9†	2.5†	4.1	8.0	10.8	31.5	41.3	41.7
West North Central States									
Duluth	0.0	0.0	0.2	1.0	1.1	1.7	4.4	19.8	45.5
Des Moines	0.0	0.0	1.3	2.5	2.4	2.2	6.4	15.9	23.7
Minneapolis	0.0	0.1	0.2	0.8	0.8	1.9	5.0	10.6	32.1
Kansas City, Mo.	0.0	0.1†	0.9†	1.6	2.8	5.7	10.6	16.2	35.6
Wichita	0.0	0.2	0.4	1.1	1.2	6.3	....	....	....
Kansas City, Kan.	0.0	0.8†	1.0	1.0	1.7	5.0	9.4	31.1	74.5‡
St. Louis	0.1	0.2†	0.7	1.6	2.1	3.9	6.5	12.1	14.7
St. Paul	0.3	0.1	0.3	0.7	1.4	3.4	3.1	9.2	12.8
Omaha	0.4	0.1	0.6	0.9	1.3	3.3	5.7	14.9	40.7
West South Central States									
Tulsa	0.0	0.0	0.4	1.1	8.3	16.2‡	....	....	....
Oklahoma City	0.0	0.1	2.6	4.3	7.4‡	....	....	....	....
El Paso	0.0	2.7	4.5	5.2	9.1	10.8	30.7	42.8	....
Dallas	0.3	0.9†	2.7†	5.1	7.3	11.2	17.2	....	....
San Antonio	0.4	0.3	2.9	4.3	4.6	9.3	23.3	29.5	35.9
Fort Worth	0.6	0.4†	2.1	4.5	5.9	6.1	16.3‡	11.9	27.8
Houston	0.8†	1.1	2.3	3.2	4.8	7.6	14.2	38.1	49.5‡
New Orleans	1.2*¶	1.4†¶	5.0†	9.6	9.9	11.6	17.5	20.9	35.6
Mountain and Pacific States									
Salt Lake City	0.0	0.1*	0.3*	0.7	1.9	6.0	9.3	13.2	41.1
Portland	0.0	0.1*	0.3	0.8	2.3	3.5	4.5	10.8	23.2
Long Beach	0.0	0.1	0.5	0.5	1.1	2.1‡	....	....	....
Oakland	0.0	0.2	0.5†	1.2	1.2	2.0	3.8	8.7	21.5
San Diego	0.0	0.2†**	0.8	1.3	1.0	1.6	7.9	17.0	10.8
Denver	0.0	0.3†	1.4	1.7	2.6	5.1	5.8	12.0	37.5
Tacoma	0.0	0.5†	0.5	0.9	1.8	3.7	2.9	10.4	19.0
Spokane	0.0	0.6†	1.2	1.0	2.2	4.4	4.9	17.1	50.3
San Francisco	0.2*††	0.1†	0.4	0.8	2.0	2.8	4.6	13.6	26.3
Seattle	0.3	0.1	0.2	0.7	2.2	2.6	2.9	5.7	25.2
Los Angeles	0.3	0.3	0.7†	0.8	1.5	3.0	3.6	10.7	19.0
Sacramento	0.9	0.4†	1.5*	6.3	...	...	...	....	....

* All typhoid deaths were stated to be in nonresidents.
† One-third or more of the reported typhoid deaths were stated to be in nonresidents.
‡ Incomplete data.
§ Special 1944 census gives rate of 0.2 for 1945 and 0.3 for 1941–45 for Washington and rate of 0.4 for 1945 and 0.2 for 1941–45 for Norfolk.
|| Special 1943 census gives rate of 1.8 for 1945 and 1.2 for 1941–45 for Richmond.
¶ Special 1943 census gives rate of 1.1 for 1945 and 1.3 for 1941–45 for New Orleans.
** Special 1944 census gives rate of 0.1 for 1941–45 for San Diego.
†† Special 1945 census gives rate of 0.1 for 1945 for San Francisco.

found among the New England cities, in '45 ⅛ (11 among 41) in this group. This in no manner detracts from the outstanding record of New England cities; rather does it show tendency for other cities to attain high standards set up by this group. 13 of large *Middle Atlantic cities* (8 in '41, 11 in '42, 15 in '43, 11 in '44) report no death from typhoid in '45. Middle Atlantic cities have group rate (0.23) higher than East North Central, New England, West North Central, and Mountain and Pacific cities. It marks highest rate for these cities since '41, when it was 0.24. Lower rates recorded for '42 (0.15), '43 (0.08) and '44 (0.17). In '43 but 11 deaths in these cities (4 in New York, 4 in Philadelphia, 3 in Pittsburgh). In '45 same cities report 26 deaths (11 in New York, 12 in Philadelphia, 3 in Pittsburgh). 5 cities (Albany, Erie, Scranton, Trenton, Yonkers) record no death

during the 5-year period '41–45. Yonkers reports no death for 7 years, Erie and Scranton none for 6 years. The one death in Paterson (in '41) was a nonresident. 4 cities (Camden, Jersey City, Syracuse, Utica) report that, for 5-year period, ⅓ or more of deaths were among nonresidents. Stated that 7 of 12 deaths in Philadelphia attributed to consumption of pastry prepared in bakery in which typhoid carrier was found. This outbreak resulted in 37 of 68 cases of typhoid reported in Philadelphia in '45. Camden reports 2 deaths, one among residents; Newark records 2 deaths, both among residents. Rate (0.62) for *South Atlantic cities* (pop. 2,727,985) higher than rate of '44 (0.22) and '43 (0.29)

TABLE 4

Number of Cities With Various Typhoid Death Rates

Year	No. of Cities	10.0 and Over	5.0 to 9.9	2.0 to 4.9	1.0 to 1.9	0.1 to 0.9	0.0
1906–1910	77	75	2	0	0	0	0
1911–1915	79	58	19	2	0	0	0
1916–1920	84	22	32	30	0	0	0
1921–1925	89	12	17	48	12	0	0
1926–1930	92	3	10	30	37	12	0
1931–1935	93	0	6	17	28	42	0
1930.....	93	2	6	30	23	22	10
1931.....	93	2	6	23	28	22	12
1932.....	93	1	7	13	29	29	14
1933.....	93	0	7	18	19	33	16
1934.....	93	0	9	11	27	23	23
1935.....	93	0	7	15	18	29	24
1936.....	93	0	3	15	21	36	18
1937.....	93	0	1	13	26	26	27
1938.....	93	0	3	13	14	34	29
1939.....	93	0	3	7	17	32	34
1940*.....	93	0	0	12	12	30	39
1941*.....	93	0	0	4	7	46	36
1942*.....	93	0	1	3	5	34	50
1945*.....	93	0	0	1	5	31	56

* Charlotte, Gary and Sacramento omitted.

but slightly lower than '42 (0.70). In these cities occurred 17 deaths in '45, 6 in '44, 8 in '43 and 19 in '42. Charlotte is only city on honor roll for '45; there were 6 such cities in '44 (Atlanta, Jacksonville, Miami, Norfolk, Tampa, Wilmington). Atlanta, Jacksonville, Norfolk and Wilmington were on honor roll in '43. 3 cities (Atlanta, Baltimore, Richmond) report that ⅓ or more of deaths were nonresidents (1 of 3 in Atlanta, 1 of 2 in Baltimore, 3 of 4 in Richmond). Although no city in this group records no death during '41–45, stated that single death in Wilmington (in '45) occurred to nonresident. Also for this 5-year period 5 cities (Atlanta, Baltimore, Charlotte, Richmond, Washington) report

TABLE 5

Total Typhoid Death Rates

	Population	Typhoid Deaths	Typhoid Death Rate per 100,000
Total of 78 Cities, 1910–45*			
1910.....	22,573,435	4,637	20.54
1911.....	23,211,341	3,950	17.02
1912.....	23,835,399	3,132	13.14
1913.....	24,457,989	3,285	13.43
1914.....	25,091,112	2,781	11.08
1915.....	25,713,346	2,434	9.47
1916.....	26,257,550	2,191	8.34
1917.....	26,865,408	2,016	7.50
1918.....	27,086,696†	1,824†	6.73
1919.....	27,735,083†	1,151†	4.15
1920.....	28,244,878	1,088	3.85
1921.....	28,859,062	1,141	3.95
1922.....	29,473,246	963	3.26
1923.....	30,087,430	950	3.16
1924.....	30,701,614	943	3.07
1925.....	31,315,598	1,079	3.44
1926.....	31,929,782	907	2.84
1927.....	32,543,966	648	1.99
1928.....	33,158,150	628	1.89
1929.....	33,772,334	537	1.59
1930.....	34,410,235	554	1.61
1931.....	34,508,750	563	1.63
1932.....	34,607,505	442	1.28
1933.....	34,708,945	423	1.22
1934.....	34,833,650	413	1.19
1935.....	35,005,351	348	0.99
1936.....	35,196,325	337	0.96
1937.....	35,386,380	289	0.82
1938.....	35,578,011	257	0.72
1939.....	35,767,022	232	0.65
1940.....	35,895,638	172	0.48
1941.....	35,895,638‡	123	0.34
1942.....	35,895,638‡	83	0.23
1943.....	35,895,638‡	78	0.22
1944.....	35,895,638‡	66	0.18
1945.....	35,895,638‡	80	0.22
Total of 93 Cities, 1935–45			
1935.....	37,025,179	385	1.04
1936.....	37,241,414	366	0.98
1937.....	37,459,339	324 †	0.86
1938.....	37,680,155	298 †	0.79
1939.....	37,900,354	259	0.68
1940.....	38,060,662	190	0.50
1941.....	38,060,662‡	141	0.37
1942.....	38,060,662‡	95	0.25
1943.....	38,060,662‡	85	0.22
1944.....	38,060,662‡	73 †	0.19
1945.....	38,060,662‡	87	0.23

* The following fifteen cities are omitted from this table because data for the full period are not available: Canton, Chattanooga, Dallas, Fort Wayne, Jacksonville, Knoxville, Long Beach, Miami, Oklahoma City, South Bend, Tampa, Tulsa, Utica, Wichita, Wilmington.

† Data for Forth Worth lacking.

‡ Census figures for 1940 used.

that ⅓ or more of deaths were among nonresidents. Baltimore reports only 11 cases of typhoid for '45, smallest number in history of that city. Charlotte has been included in group for fourth time; however, for purposes of adequate comparison, figures for this city

omitted in calculating rates for group as a whole. ***East North Central cities*** (pop. 9,386,378) have regained first place, which rank they held in '41 and '38. 13 (12 exclusive of Gary) cities in this group (Akron, Canton, Cleveland, Evansville, Flint, Fort Wayne, Gary, Grand Rapids, Milwaukee, Peoria, South Bend, Toledo, Youngstown) report no death from typhoid in '45. Cleveland is newcomer to honor roll. Gary added to this group in '40, but figures for this city omitted in determining rates for group as a whole. In East North Central cities there occurred 7 deaths in '45 (rate 0.07), 13 in '44 (rate 0.14), 24 in '43 (rate 0.26) and 13 in '42 (rate 0.14). 5 cities (Canton, Evansville, Fort Wayne, Gary, Grand Rapids) record no death during 5-year period '41–45. Canton and Grand Rapids report no death for 6 years. Stated that single death in Akron (in '44), in South Bend (in '44) and in Youngstown (in '41) occurred among nonresidents. ***Central group*** (pop. 1,286,747) show a definite increase in death rate (0.70 in '45, 0.31 in '44, 0.62 in '43, 0.54 in '42). This group has the highest rate for '45, West South Central cities being next (0.59). Effect of hospitalizing cases from surrounding rural areas remains evident. Of 9 deaths in '45, 7 were nonresidents (3 of 4 deaths in '44, 5 of 8 in '43, 6 of 7 in '42). Two cities (Chattanooga and Memphis) report no deaths among either residents or nonresidents and appear on the honor roll. The one death each in Knoxville and Nashville were stated to be among nonresidents. Of 2 deaths among residents in this group of cities, one each occurred in Birmingham and Louisville. Although no city in this group reports no death during the 5-year period '41–'45, stated that all 7 deaths in Knoxville and 4 deaths in Nashville occurred among nonresidents. Also for this 5-year period 3 cities (Birmingham, Louisville, Memphis) report that ⅓ or more of deaths

TABLE 6

Total Typhoid Death Rate per 100,000 Population of 93 Cities, by Geographic Divisions, 1931–45

Area	Population*	Typhoid Deaths			Typhoid Death Rates			
		1945	1944	1943	1945	1941–1945	1936–1940	1931–1935
New England	2,579,152	2	1	6	0.08	0.14	0.39	0.70
Middle Atlantic	13,129,185	30	22	11	0.23	0.17	0.43	0.80
South Atlantic	2,727,985	17	6	8	0.62	0.54	1.14	2.70
East North Central	9,386,378	7	13	24	0.07	0.16	0.53	0.75
East South Central	1,286,747	9	4	8	0.70	0.57	2.54	4.81
West North Central	2,716,484	3	3	3	0.11	0.16	0.60	1.24
West South Central	2,048,692	12	19	17	0.59	0.89	3.09	5.36
Mountain and Pacific	4,186,039	7	5	8	0.17	0.23	0.60	0.88

* Census figures for 1940 used.

5 cities (Cincinnati, Columbus, Dayton, Indianapolis, Peoria) report that for the 5-year period ⅓ or more of deaths were nonresidents. Detroit recorded no death among residents in '42, again in '45. Increase in deaths in this group of cities in '43 due primarily to high incidence of disease in Toledo, 13 of 24 deaths occurring there. Stated that practically all cases traced either to one carrier, a food handler, or to cases resulting from contact with that carrier. Chicago reports but a single death for each of 3 years '43–'45. Cincinnati records 2 deaths in '45 (one among residents), none in '44 and 3 in '43 (all nonresidents). Detroit reports one among nonresidents in '45, 3 in '44 (1 among nonresidents) and two in '43 (both among residents). 6 cities in ***East South*** were among nonresidents. For '45 there are recorded 5 deaths in Birmingham (4 among nonresidents), 2 in Louisville (one among nonresidents). ***West North Central cities*** (pop. 2,716,484) maintain their consistently low rate (0.11 for each of past 3 years, '43–'45). Death rate declined from 0.29 in '41 to 0.18 in '42 and 0.11 in '43, where it has remained. In each of the last 3 years there have occurred 3 deaths. 6 cities (Des Moines, Duluth, Kansas City, Kan., Kansas City, Mo., Minneapolis, Wichita) record no death in '45. There were 7 such cities in '44, 7 in '43 and 5 in '42. 3 cities (Omaha, St. Louis, St. Paul) report one death each in '45, all among residents. 2 cities (Des Moines, Duluth) record no death during 5-year period '41–'45. 3 cities (Kansas City, Kan.; Kansas City,

Mo.; St. Louis) report that, for 5-year period, ⅓ or more of deaths were among nonresidents. Duluth reports no death for 7 years; Des Moines none for 6 years. 8 cities of *West South Central group* (pop. 2,048,692) report continued reduction in rate and establish new low rate of 0.59 for group. In these cities there occurred 12 deaths in '45, 19 in '44 (rate 0.93), 17 in '43 (rate 0.83) and 15 in '42 (rate 0.73). Of 12 deaths in this group of cities in '45, 8 were among nonresidents (8 of 19 in '44, 8 of 17 in '43, 6 of 15 in '42). Tulsa reports no death during the past 6 years. 4 cities (Dallas, El Paso, Fort Worth, New Orleans) report that, for 5-year period '41–'45, ⅓ or more of deaths were among nonresidents. 3 cities (El Paso, Oklahoma City, Tulsa) record no death in '45 and New Orleans reports 6 deaths, all among nonresidents. Houston reports 3 deaths, 2 among nonresidents. 11 cities (excluding Sacramento) in the Mountain and Pacific states (pop. 4,186,039) report decrease from 16 deaths in '41 (rate 0.38) to 13 in '42 (rate 0.31), to 8 in '43 (rate 0.19), and to 5 in '44 (rate 0.12) and an increase to 7 in '45 (rate 0.17). This group stands in fourth place in '45. Sacramento again omitted in calculating total number of deaths and rates. This city reports one death among residents in '45 (no death in '42–'44). Although no city in this group records no death during the period '41–'45, stated that single death in Portland (in '44) and in Salt Lake City (in '41) occurred among nonresidents. Also 6 cities (Denver, Sacramento, San Diego, San Francisco, Spokane, Tacoma) report that ⅓ or more of deaths were nonresidents. 8 of *Mountain and Pacific cities* (Denver, Long Beach, Oakland, Portland, Salt Lake City, San Diego, Spokane, Tacoma) report no death from typhoid in '45. There were 9 such cities in '44, 7 in '43 and 7 in '42. Stated that the one death in San Francisco in '45 was nonresident. Los Angeles records 5 deaths, all residents. The honor roll of cities with no death from typhoid increased from 50 in '42 to 56 in '45. 2 of 3 cities (Charlotte, Gary) not included in 93 (Table 4) also report no death. When corrected for residents, no cities remain with rates of 2.0 or more. There were 4 deaths, 3 nonresidents, in Richmond, giving on basis of '40 census a rate of 2.1. Using '43 special census, rate for this city becomes 1.8. Charge of nonresident deaths continues to account in part for remaining high rates, especially in southern cities. Number of cities with rates less than 1.0 increased by 3 (eighty-seven in '45, 84 in '42). 40 cities (41 with Gary) record no typhoid death in '44 and '45 (Table 2). Again emphasized that several other cities in first rank would appear in honor roll were they not charged with nonresident deaths. For 78 cities (Table 5) for which data available since '10 there occurred 80 deaths from typhoid in '45 (66 in '44 and 78 in '43). Lowest number is that for '44, with rate of 0.18 per 100,000 of pop. For 93 cities, number of deaths in '45 is 87 (73 in '44 and 85 in '43). Table 5 shows number of deaths for each of past 3 years in each group of cities. It also shows rates for '45 and '41–'45 and 2 preceding 5-year periods. For '41–'45 rate for New England cities (0.14) marks distinctly new record and is followed by East North Central and West North Central cities (0.16) and Middle Atlantic cities (0.17). Reduction in rates for all groups by 5-year periods is most impressive. For '45 health officers report no special outbreaks of typhoid. Improvement general throughout the country, and war years do not appear to have contributed materially to typhoid problem in large cities.—*Ed.*

Typhoid Fever. Health Problems in Uruguay. C. FABINI. Bol. Salud Publica. (Arg.) **9**: 71 (May–Aug. '45). Typhoid fever and diphtheria, says author, differ fundamentally from diseases such as tuberculosis and syphilis in that whereas latter closely connected with economic and social problems, organized sanitation will bring about surprising results with former, and he cites practical disappearance of typhoid fever and diphtheria from Canada and U.S. Notification of typhoid fever in Uruguay in past very inadequate and incomplete. Thus, in '29, notifications totaled 328, and 174 deaths registered, which would, if correct, imply 50% fatality rate. Taking 10% as avg. fatality, cases, and therefore notifications, should number 1740. Outbreak of '44 not really limited to that year, but was peak of outbreak which had been increasing for 4 yr., from '41, numbers of cases in successive years being 570, 1013, 2152 and 2544. Causes assigned are provision of unpotable water, lack of proper sanitation, and defective health education. In Fray Bentos, among pop. of 9500, there were 302 cases (3.18%) and 15 deaths, case mortality of 4.96%. This outbreak shown to be due to contamd. water supply; it contained fecal *Esch. coli* and was not chlorinated. There was an epidemic in Montevideo in '44, in which 1113 cases were notified, 561 males,

552 females; 176 (15.8%) of patients under 10 years of age, 292 (26.2%) were in second decade, 261 (23.4 in third and 160 (14.3) in fourth. Fatality rate high, 132 deaths occurring, 11.8%, and rate increased with age: 4.5, 9.5, 11.1, 15.6, 16.6, 35.1 and 38.4%, last figure including all over age of 60 years. Distr. of cases in 37 wards of municipality given; 319, or just over one-third, of 914 patients whose residence was known came from Central dist. Causes assigned various: eating raw vegetables, in particular watercress, drinking water shown by examn. to be contamd., by agency of convalescent carrier, etc. Water seemed to be chief source of infection, but if this was so "one would have expected number of cases to be greater." Plans for remedying this state of affairs were on usual lines: Improvement of water supply and care to see that contamn., especially fecal contamn. of it, prevented. Secondly, by vaccination of people. More than 100,000 persons vaccinated at 30 centers set up in town. Thirdly, educative measures including information and announcements in press, propaganda by radio and cinema, and by lectures and talks in schools. Lastly, discovery and treatment of carriers. Discovery not so difficult; thus, of 95 examd. by duodenal sound, 75 positive for *Eberthella typhosa*. Some treated with iodophthalein, 4 gm. by mouth, with orange juice, thrice weekly for 3 mo. In 20 of 65 so treated bile became sterile; 16 of them continued to excrete bacteria in spite of bile remaining sterile. Sulphaguanidine, 0.05 gm. per kg. bodyweight, tried in 5 exclusively intestinal carriers, but without success. Regulations made for control of carriers; they had to report their place of abode, occupation, etc., and directions given on general san., hand-washing, etc. Suggestions made for intensification of vaccination, for better collaboration with doctors and more complete notification, for more strict control of carriers and for fuller program for improving general san. of dist. —*B. H.*

Distribution of Iodine in the Fresh Waters of the Upper Svanety Region and Its Correlation With Occurrence of Endemic Goiter. E. V. MENZHINSKAYA. Trav. lab. biogeochim. acad. sci. U.R.S.S. (U.S.S.R.) **7**: 26 ('44). Various rivers and springs of upper Svanety sampled for their iodine (I) content. In general, these waters have low content of I, varying from 0.2×10^{-7}% to 5.5×10^{-7}%. Difference in content of I between river and spring water not great. For Ingur river, content of I slightly higher downstream, and content of I in right tributaries little higher than left tributaries. Higher I contents found in places where tributaries join Ingur, since agitation of water keeps considerable alluvium suspended at these points. Correlation found between occurence of endemic goiter and iodine content of rivers and springs. It would be desirable to investigate influence of I content of various mineral springs on I content of bodies of water into which they empty.—*C.A.*

An Epidemic of Infectious Hepatitis Apparently Due to a Water-Borne Agent. JOHN R. NEEFE & JOSEPH STOKES JR. J. Am. Med. Assn. **128**: 1063 ('45). During late summer of '44, 350 of 572 persons in camp for boys and girls located near Philadelphia developed infectious hepatitis but no deaths within period of 13 wks. Authors state: Outstanding characteristics of epidemic were (1) unusually high incidence of disease, (2) higher total incidence in female than in male group, (3) predominance of early cases in female group and of later cases in male group, (4) simultaneous infection of number of persons at camp who had not been in personal contact with one another and (5) apparent ease with which infectious agent acquired . . . by those in contact with infected persons away from camp." Human volunteers inoculated with blood serum, nasopharyngeal washings, urine, and feces collected from camp patients as well as with well water and prepn. made from camp flies. Information obtained from these expts. summarized: (1) fly prepn., nasopharyngeal washings, and urine did not produce disease; (2) blood serum injected parenterally did not produce hepatitis, but did if administered orally and after an incubation period similar to that observed at camp; (3) feces of infected persons did produce disease and was predominant cause; (4) feces filtrate from Seitz filtration produced disease; (5) decrease in the quant. of agent administered orally apparently resulted in increase in length of incubation period; and (6) water from females' well produced mild illness associated with hepatic dysfunction similar to that produced by the fecal matter, and such patients showed immunity to infection from feces agent. Bacteriologic studies provided evidence that females' well water contamd. with fecal matter. Nearby cesspool which continuously received excreta from infected persons probable source. Air-borne agents,

fomites, biting insects, personal contacts, food, milk, and water, both lake and drinking, considered to be potential vehicles for transmission, but evidence indicated that drinking water would be only vehicle that could transmit logically causative agent of epidemic hepatitis. Based on epidemiologic observations, bacteriologic studies, and transmission expts. in volunteers, authors conclude: "(1) Evidence indicates that agent responsible for this epidemic water borne. (2) Causative agent of infectious hepatitis excreted in feces of persons with disease. Evidence presented herein confirms observations of others in this respect. (3) Anything subject to direct or indirect contamn. with feces provides potential means of transmission of this disease. (4) This appears to be first epidemic of infectious hepatitis (not homologous serum hepatitis) in which exptl. evidence of method of transmission has been obtained. As far as known, this also appears to be first satisfactory evidence of natural transmission to man of any virus agent by water "—*P.H.E.A.*

The Effect of Chlorination on the Virus of Eastern Equine Encephalomyelitis in the Presence of Organic Substances. J. E. KEMPF, M. E. PIERCE, M. G. WILSON & M. H. SOULE. J. Infectious Diseases. **76**: 120 ('45). Results of previous investigations by authors have shown that virus of poliomyelitis resistant to much greater concns. of chlorine than normally used for protecting municipal water supplies. After outbreak of war, impossible to make further studies on effect of chlorination on virus of poliomyelitis, since supplies of monkeys required for expts. no longer available. In present paper, expts. to det. effect of chlorine on virus of eastern equine encephalomyelitis, both in presence and absence of org. substances, described. Virus of encephalomyelitis chosen for this investigation because of its similarity to that of poliomyelitis, and because large numbers of white mice, which are highly susceptible to disease, available. In first series of expts., virucidal action of chlorine on suspensions from which org. material had been removed by centrifuging detd. To each of series of 200-ml. samples of solns. contg. known concns. of chlorine (detd. by *o*-tolidine and starch-iodide tests), 0.02 ml. of suspension of virus, in which virulence varied from 1 to 1000 median lethal doses (MLDs) per 0.03 ml., added. Treated suspensions allowed to stand for 10 min. at room temp. before being injected into mice. For each inoculation 0.03 ml. of suspension taken. Control expts. made with untreated suspensions. All treated mice kept under observation for 10 days; it was considered that virus in suspensions which after inoculation did not cause death within this period had been inactivated by chlorine. Concns. of chlorine greater than 0.63 and 0.71 ppm., as detd. by *o*-tolidine and starch-iodide tests respectively, consistently inactivated virus, and concns. of less than 0.30 and 0.36 ppm. chlorine as detd. by same 2 methods, had no virucidal action. Variable results obtained at concns. between figures mentioned above. In second series of expts., virucidal action of chlorine on suspensions contg. various types of org. material detd. To samples of suspension of virus from which org. matter initially present had been removed by centrifuging, 0.75% suspensions of tissue from spinal cord of monkeys, 0.01 and 0.02% solns. of gelatin, and water from Huron R. added, resulting mixts. each treated with different amts. of chlorine, and procedure adopted in first series of expts. followed. Control expts. made as before, except in case of suspensions contg. river water. In every case, concns. of chlorine required to inactivate virus greater for suspensions contg. org. material than for untreated suspensions; protective action of gelatin on virus directly related to concn. of gelatin. Expts. also made to det. effect of break-point chlorination on river water contg. virus. Results obtained inconsistent, but it was concluded that virus would be inactivated in water contg. chlorine in excess of amt. required to reach break-point. Attempts to reactivate virus in chlorinated suspensions unsuccessful.—*W.P.R.*

Allergy and Your Water Supply. GEORGE H. COOMBS. J. Maine Med. Assn. **37**: 98 (Apr. '46). Water produced in your community may be best in state, but it is not good enough for number of citizens who have allergy to certain minerals that appear in water. This especially true of those who suffer from arthritis. This interesting article explains that although state labs. make tests for typhoid fever and other diseases resulting from poln., lack of personnel does not permit them to make complete anal. of samples to be tested. As author expresses it, "What is one man's meat is another one's poison," is sufficient reason to justify adequate number of personnel by various state boards of health to make complete anal. of water samples submitted for testing.—*Ed.*

WELLS AND GROUND WATER

Regulations in Regard to New Wells and Boreholes. *Instructions issued by Dept. of Scientific and Industrial Research.* Wtr. & Wtr. Eng. (Br.) **48**: 591 (Nov. '45). Attention of well-drillers, water engrs., and persons concerned directed to provisions of Water Act of '45. Person proposing to sink well to depth of more than 50′ shall, before he begins to do so, give Com. of Privy Council for Scientific and Industrial Research notice of intention. Person sinking such well shall, on completion or abandonment of work, send copy of journal kept to said com. together with particulars of any test made. Purpose of provisions is to insure, in national interest, that all scientific information obtainable be collected and available for information of all concerned with water supply. Cores, when taken, should be laid out in regular order with marks at intervals showing depths of origin, and gaps in which cores absent or imperfect should be marked with indication of extent of missing core.—*H. E. Babbitt.*

Ground Water Conditions in Elm Creek Valley, Barber County, Kansas, With Special Reference to Contamination of Ground by Oil-Field Brine. CHARLES C. WILLIAMS & CHARLES K. BAYNE. Kansas Geol. Survey, Bul. **64**, 81 ('46). Water from Cedar Hills sandstone very hard (mostly noncarbonate hardness). Total hardness varies from 344 to 2096 ppm. Locally water salty. Water from Gerlane formation of better quality than water from other formations. Chem. character of water in alluvium of Elm Creek Valley varies greatly, and is affected by water from Cedar Hills sandstone and oil-field brine. Dissolved solids range from 273 to 11,680 ppm. Sulfate content greatest near valley edge (708 ppm.). Brine associated with petroleum deposits contains more dissolved mineral matter than sea water, varying from 212,400 to 214,900 ppm. Anals. of water given.—*C.A.*

Ground Water in Louisiana. PAUL H. JONES. Louisiana State Univ. Eng. Expt. Sta. News **2**: 10 (Jan. '46). Perhaps two-thirds of total annual withdrawal, avg. 500 mgd., is for irrigation, principally rice fields, with some for strawberry farming, to supplement rainfall. Single continuous aquifer underlies entire southwestern Louisiana rice-producing area. Although ground water for southeastern Louisiana strawberries derived exclusively from flowing wells, many being allowed to dischg. continuously, wasting 35 mgd. in St. Tammany Parish alone, artesian pressures have not declined seriously during past several years. Up to 200 mgd. max. used by industry for cooling, makeup water and washing. In Baton Rouge industrial zone about 70 mgd. withdrawn. Of 219 municipal water supplies, 190 use wells; consumption is at least 50 mgd. Continuous water level recorders installed in 21 wells and periodic measurements made in some 280 others. Map recognizes occurrence of ground water in 6 zones, depending on hardness, availability and salinity. Water obtainable from Eocene, Miocene and Pleistocene formations; none in Oligocene structures. Publications and memoranda relative to ground water investigations in Louisiana listed.—*A. A. Hirsch.*

Geology and Ground-Water Resources of Scotts Bluff County, Neb. L. K. WENZEL, R. C. CADY & H. A. WAITE. U.S. Geological Survey Water Supply Paper 943, 150 pp. ('46). Scotts Bluff County is in westernmost Nebraska, adjacent to Wyoming state line. County includes valley of North Platte R. and adjacent uplands and is underlain by formations ranging in age from Cretaceous to Recent. Oldest exposed formation is Lance, of Cretaceous age, which is overlain successively by Chadron and Brule formations, of Oligocene age; Gering sandstone and sandstones of Arikaree group, of Miocene age; and alluvium of Pleistocene and Recent age. Of these formations principal aquifers are Lance and Brule formations and Pleistocene alluvium. Most productive wells, including most of those pumped for irrigation, munic. and indus. supplies, obtain water from Pleistocene and Recent sand and gravel in inner valley of North Platte R. Many of these wells yield as much as 1000 gpm. Most farm wells obtain small but adequate supplies from cracks and crevices in Brule formation and few wells in western part of county tap water in Lance. Water from Pleistocene and Recent alluvium and Brule of good qual., but that from Lance rather highly mineralized. Water table in Scotts Bluff County has been raised as much as 50′ in some places by seepage of water diverted from North Platte R. for irrigation. Effect of this seepage of

irrigation water on water levels in wells, movement, discharge and recharge of ground water, and depth to water in county discussed. Report based on investigation made in co-operation with Conservation and Survey Div. of Univ. of Nebraska.—*Ed.*

Drilling for Water in Great Britain during Wartime. F. H. EDMUNDS. Wtr. and Wtr. Eng. (Br.) **49**: 69 (Feb. '46). Drilling in Britain requires high degree of technical skill because of varied geological structures. Some 250 firms engaged in drilling; probably 70% of work carried out by 20 larger concerns capable of drilling to depths of 1500′ or more, although few holes go below 1000′ and 300′ is avg. While holes 12–30″ in diam. common, majority smaller. Army utilized its own well-drilling units in Britain as well as overseas. Demand for drilling pressing throughout war. Over 200 boreholes 12–18″ in diam. and of avg. depth of about 300′, with yields of 80,000 to 120,000 gpd. (Imp.) constructed under govt. contract for supply of airfields. Probably 3000 8″ diam. or larger holes put down. Many thousand shallow holes for prospecting for coal occupied skilled labor and small rigs. All firms suffered lack of labor and transportation.—*H. E. Babbitt.*

The Hydrogeology of Southern East Anglia. A. W. WOODLAND. Wtr. and Wtr. Eng. (Br.), **49**: 504 (Sept. '46). Inst. of Water Engrs., Southeastern Sec., Feb. 26, '46. Formations of importance from hydrogeological view are: Glacial Drift—boulder clay, glacial sands and gravels. Pliocene—crag. Eocene—London clay, Woolwich and Reading beds, and Thanet beds. Cretacious—chalk. Valley deposits include modern alluvium and terrace deposits. Boulder clay consists of unstratified, stony clay with occasional lenses and streaks of sand and gravel. Glacial sands and gravel underlie and spread beyond limits of boulder clay. Crag consists at depth of grayish and greenish sands, often crowded with shells. London clay consists mainly of stiff dark clay which yields no water. Lower London tertiaries comprise both Woolwich and Reading beds and Thanet beds. Chalk is divided into Lower, Middle and Upper. About 300 mgd. (Imp.) enter chalk as result of rainfall. Total replenishment, due to surface runoff is 600 mgd. (Imp.). Chalk varies much in capacity to yield water. Virtually all water available in chalk contained in top 150 to 200′. Chemically waters from chalk may be divided: (1) normal chalk water, characterized by hardness of about 300 ppm., (2) Breckland water having temporary hardness of only about 100 to 150 ppm., (3) boulder clay waters in which hardness is excessive, (4) saline waters of coastal belt of Suffolk, (5) waters of synclinal area of central Suffolk in which concns. of salts not so high as coastal waters, (6) soft alkaline waters of southeastern Essex.—*H. E. Babbitt.*

Present Ground Water Investigations in the Netherlands. W. F. J. M. KRUL & F. A. LIEFRINCK. Elsevier Pub. Co., Inc., N.Y.-Amsterdam ('46). This 78-p. booklet, in English, full of interesting information on special ground water problems existing in Netherlands and means employed to solve them. Geologic structure briefly described and shown that most of ground water comes from Pleistocene and alluvial deposits. Recharge either in sand dunes or hills. Ground water, although at present the main source of water supply, limited, and use of surface water increasing. Problems involved in this limitation discussed, including study of amounts of ground water that can safely be taken without unduly increasing salt content by raising salt water level. Such conditions exist not only in dune region, but also in polders (land that is kept dry artificially). Studies made, by the use of lysometers, on "effective" rainfall, that is, part of total pptn. which actually reaches ground water table. Ground water replenishment from surface streams practiced locally and its effect carefully checked by test wells and computations. Many public constr. works requiring deep excavations studied to forecast the pumpage necessary and form of water table caused by this pumpage. Permeabilities detd. by extensive pumping tests, based upon a specially developed theory in which line of depression is detd. by a Bessel function. Final formulas used presented, but not their derivations. Constr. of new polders in former Zuider Zee presented addnl. problems whose soln., based on theory, could be checked by field studies after constr. completed. Many problems too complex for math. anal. investigated by original model research. In this work 3-dimensional elec. similarity models developed, and use made of thin layer flow of liquids of high viscosity and of large scale models. Interesting bibliography appended.—*Max Suter.*